MAY 1959

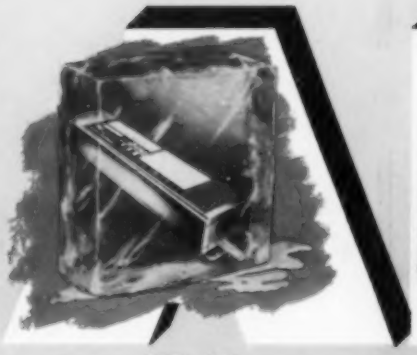
ie

ILLUMINATING ENGINEERING

Journal of the
ILLUMINATING ENGINEERING SOCIETY

1sts

from the world's largest exclusive fluorescent lamp ballast manufacturer



KOOL KOIL
FLUORESCENT LAMP BALLASTS

SINGLE CASE BALLAST
TO OPERATE VHO, SHO, PG LAMPS

ADVAN guard

THERMALLY ACTUATED
PROTECTIVE DEVICE

VISI-VOLT COLOR CODED LABELS FOR
POSITIVE VOLTAGE IDENTIFICATON

INDIVIDUAL PACKAGING OF
FLUORESCENT LAMP BALLASTS

SEND FOR FLUORESCENT
LAMP BALLAST MANUAL

NATIONWIDE SERVICE
STOCKING DISTRIBUTOR PLAN

FLB SERVICE
WARRANTY PROGRAM

"The Heart of the Lighting Industry."

ADVANCE®
TRANSFORMER CO.
2950 NO. WESTERN AVE CHICAGO 18 ILL U.S.A.

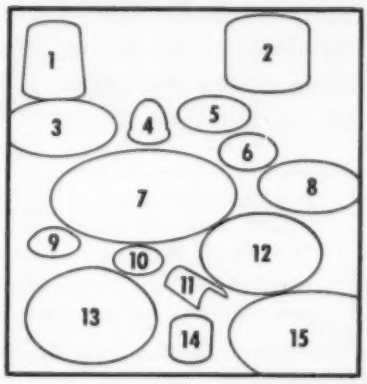
Can you match the glass to the application?

These 15 special glass products for controlling light are just part of the complete service you can get from us.

You can use our staff and research facilities to solve optical problems or to substantiate your own findings.

Then you can use our glass know-how and production facilities to get exactly what you need, when you need it, at a price that makes sense.

Inquiries invited. Write to Lighting Sales Division, Corning Glass Works, 33 Crystal Street, Corning, N. Y.

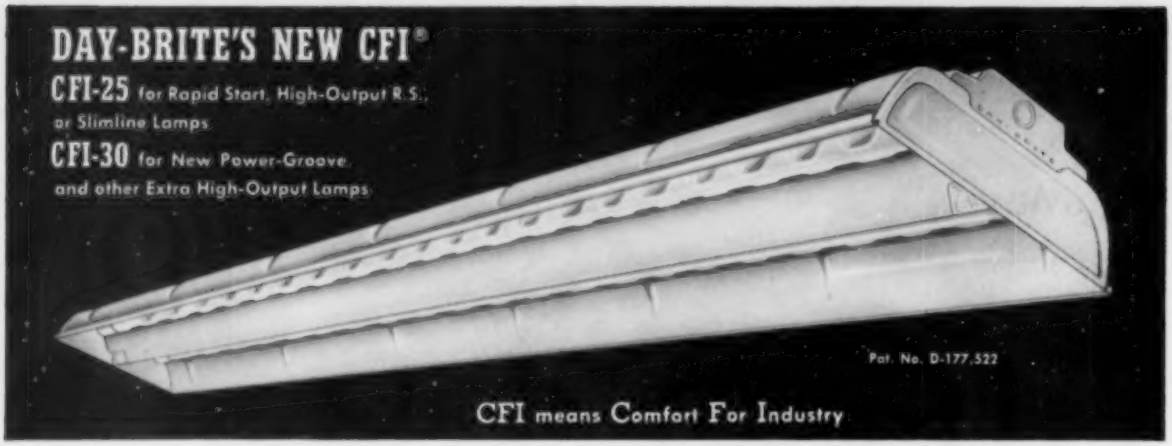


1. Airport Threshold 2. Radio Tower 3. Stage Spot 4. Hazardous Area, Explosive 5. Service Station Sign 6. Railroad Signal 7. Movie Studio 8. Traffic Signal 9. Locomotive Marker 10. Switch Lamp 11. Aviation Filter 12. Underpass 13. Airport Runway 14. Surgical Lamp Filter 15. Sports Area

CORNING GLASS WORKS

CORNING MEANS RESEARCH IN GLASS

Today's Best Lighting Value for Every Industrial Application


DAY-BRITE'S NEW CFI®
CFI-25 for Rapid Start, High-Output R.S., or Slimline Lamps
CFI-30 for New Power-Groove and other Extra High-Output Lamps
Pat. No. D-177,522
CFI means Comfort For Industry

25% uplight washes out harsh ceiling contrasts. "Up-draft" action provides more efficient self-cleaning. Center "V" and closed ends for added shielding and strength. Reflection surfaces are lifetime porcelain enamel for easy cleaning. 8-foot rigid channel, one-piece reflector for simplified installation. Spring-loaded sockets hold lamps securely, speed relamping. *All this at up to 17.7% lower cost!*

Get the FACTS...and the FIXTURES

Now industrial fixture buyers can get more light with greater eye comfort at lower installed cost, lower operating cost, and with lower annual owning costs. Today's lower-priced Day-Brite CFI-30, used with new Power-Groove lamps, actually reduces the cost of lighting industrial areas *as much as 54%*. For detailed information, call your Day-Brite representative listed in the Yellow Pages of your phone book. Or use the coupon below.

Day-Brite Lighting, Inc.
6258 N. Broadway
St. Louis 15, Missouri

GENTLEMEN: Please send me information about Day-Brite's new CFI fixture and "Operation Uplight."

Name_____

Title_____

Firm_____

Address_____

City_____ Zone____ State____

Look for this emblem displayed by Distributors offering Day-Brite Comfort for Industry fixtures—available now for immediate delivery!

A-120 © 1959 by Day-Brite Lighting, Inc.

eye-li
DELIGHTFULLY BETTER
DAY-BRITE
LIGHTING FIXTURES

DAY-BRITE LIGHTING, INC.
St. Louis, Mo. • Santa Clara, Calif.

NATION'S LARGEST MANUFACTURER OF COMMERCIAL AND INDUSTRIAL LIGHTING EQUIPMENT

ie

ILLUMINATING ENGINEERING

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

May
1959

Vol. LIV, No. 5

1958-1959 Officers
President
George J. Taylor
Vice-President
J. B. Browder
Vice-President
R. G. Slauer
General Secretary
J. R. Chambers
Treasurer
G. Franklin Dean

Editor
Ruby Redford

Advertising Manager
Clayton E. Ellis

Assistants
Barbara Lamson, Editorial
Adelaide Philiba, Advertising

Publications Committee
R. M. Zabel, Chairman
Brooks Chassaing
Eve Freyer
W. P. Lowell, Jr.
R. W. Morris
J. S. Schuchert
F. W. Sell

Managing Director
A. D. Hinckley
Technical Director
C. L. Crouch

Contents

253 Imaginative Installations

258 New Bank Building

259 Design and Evaluation of High Utilization Fluorescent Street Lighting Luminaire — D. E. Husby

265 A Demonstration Laboratory for Roadway Lighting — R. M. Swetland and K. D. Tobin

273 IES Lighting Data Sheet — Series XXIV
Lighting a Shoe Store (12-113)

275 High Levels in a Multi-Use Arena

277 Theoretical and Practical Light Distributions for Roadway Lighting — A. W. Fowle and R. L. Kaercher

291 Computation of Relative Comfort and Relative Visibility Factor Ratings for Roadway Lighting — Charles H. Rex

5A Lighting News
Here and There with IES Members, 6A; From the Desk of the President, 20A; It Seems to Me, 23A; About People, 24A; Books and Pamphlets, 28A; New Members, 28A

45A Index to Advertisers

Sustaining Members — Refer to March 1959 ILLUMINATING ENGINEERING

Committee Personnel — Refer to April 1959 ILLUMINATING ENGINEERING

STATEMENTS and opinions in articles and papers in ILLUMINATING ENGINEERING are the expressions of contributors and do not necessarily represent the policies or opinions of the Society. Official Society opinions are expressed only in official committee reports specifically approved by the Council of the Illuminating Engineering Society.

ILLUMINATING ENGINEERING SOCIETY

EDITORIAL and advertising offices
1860 Broadway, New York 23, N. Y.

PUBLICATION office 32d Street & Elm Avenue, Baltimore 11, Md.

Founded 1906

ILLUMINATING ENGINEERING: The Journal of the Illuminating Engineering Society. Copyright 1959 by the Illuminating Engineering Society. Published monthly in the United States of America. Entered as second-class matter at the Post Office, Baltimore, Md. Acceptance for mailing at special postage rates provided for in Section 1103 P.L.&R., Act of October 3, 1917. Authorized July 16, 1918. ¶ Subscription $18 per year plus extra postage to all countries to which second-class postage rates do not apply; single copies $1.50. ¶ Address changes must be received at I.E.S. headquarters by the first of the month to be effective with the issue of the next succeeding month.

INSTALLATION: Lowell Five Cent Savings Bank
North Chelmsford Branch
North Chelmsford, Massachusetts

ARCHITECT: Arthur Englund, Lowell, Massachusetts

ELECTRICAL CONTRACTOR: J. M. Richards Company
Lowell, Massachusetts

DISTRIBUTOR: Frank P. McCartin Company
Lowell, Massachusetts

FIXTURES: Litecontrol #1548-RS and #1524-RS troffers with Holophane #6010 CONTROLENS*

FIXTURE SPACING: 8'-0" on centers

CEILING HEIGHT: 9'-5"

INTENSITY: Average 55 Footcandles in Service

Bank Interest Item:

New, Lower Brightness Lighting

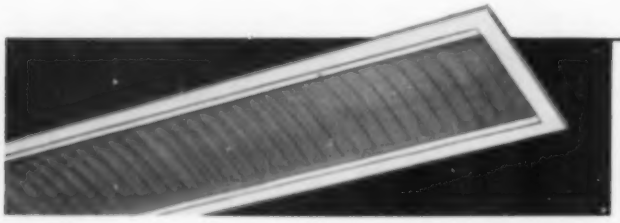
– by LITECONTROL

Very efficient lighting at sensible first cost (and upkeep) is being "deposited" at this branch bank. The desirable low brightness was achieved by LITECONTROL troffers which use the new Holophane 6010 concave acrylic plastic lens to excellent advantage. You couldn't ask for more comfortable lighting. Four feet long, the lens is lightweight . . . easy to handle . . . shatterproof.

The fixture has a removable hinged door, which may be installed to open from either side. A trigger catch permits simplified access. Maintenance and cleaning are easy indeed.

Many branch banks (main ones too), stores, offices, hospitals, libraries can use lighting like this. It's eminently practical. And inexpensive, too. Think of LITECONTROL for your next job.

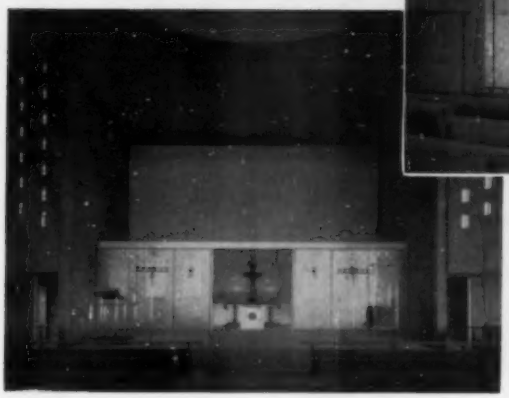
*Reg. Holophane Company, Inc.



LITECONTROL
Fixtures
KEEP UPKEEP DOWN
LITECONTROL CORPORATION,
36 Pleasant Street, Watertown 72, Massachusetts

DESIGNERS, ENGINEERS AND MANUFACTURERS OF FLUORESCENT LIGHTING EQUIPMENT DISTRIBUTED ONLY THROUGH ACCREDITED WHOLESALERS

Golden dome and altar area at St. Mary's Greek Orthodox Church.



Most consultants will agree that for imaginative application of lighting principles, areas requiring a given "atmosphere" are the most rewarding opportunity. This factor is more and more being planned into the lighting for a great many areas—certainly stores, even offices. But it is always a requisite for churches. Added to the imagination required, there usually are severe budget considerations, difficult construction problems, and sometimes multiple use.

Imaginative Installations

Churches

The two churches shown, on this and the following page, are a case in point. Each has its own esthetic aim, though different, the usual problems of height and shape of the area, and multiple service for worship and as a cultural and social center for its people.

The first, St. Mary's Greek Orthodox Church, in Minneapolis, has been designed to express the ancient spirit and liturgy of the Greek Eastern Orthodox Church in the contemporary idiom. And its lighting is designed for integration with the spacial theme of this architecture.

Its golden dome, identifying it as a Greek Church, is the significant architectural element. In the lighting design, the highest surface illumination (except for the altar area) occurs on the white interior surface of the dome. Low dark ceilings contrast with the high white ceilings, still further building up the effect of this traditional feature of the church.

Outdoors at night, this gold anodized aluminum dome is floodlighted for visibility 180 degrees around. Eight 500-watt PAR 64 floods mounted at the eight outer corners of the roof achieve this.

Within the church, decorative lighting elements combine with functional lighting (for the most part from invisible sources), each in addition serving to enhance the architectural "atmosphere." Downlight soffits using 100-watt lamps are recessed in the lower ceiling to provide 17 footcandles in the nave. These levels may be lowered by dimmer control, for certain parts of the service. The altar is lighted to 50 footcandles by a combination of downlights, light from the dome, and one 300-watt PAR 56 spot lamps. Next to the altar, the dome itself is the most significant element. This is indirectly lighted with 24 adjustable incandescent units, four feet on centers, and is further highlighted with a 150-watt PAR 38 floodlamp.

The design is by John Rauma of Thorshov & Cerny, Inc., architects and engineers in Minneapolis. It was awarded first prize in the 1958 MMILJ contest conducted by the Twin City Section of IES.

St. Thomas Acquinas—church of contemporary design.

A totally different but equally appropriate design is that shown in this installation, for St. Thomas Acquinas Church (R. C.) in Toledo, Ohio. This church is of contemporary design by Britsch Macelwane Associates, Architects, and has a relatively low (for churches) ceiling. No hanging fixtures are used; decorative lighting serves also as functional lighting, to a level of approximately 45 footcandles at the pews, higher at the altar. The nave itself consists of three major areas, from the lighting design standpoint. These are: under the balcony, the choir loft, and the main nave itself. Mounting height under the balcony is quite low. Very shallow well-shielded low brightness luminaires are used here, each having four 40-watt cool white rapid start lamps. They use clear plastic enclosures having precisely designed refracting angles so as to provide high levels without direct or reflected glare. Spacing of these units was dictated by the location of the exposed beams on the underside of the balcony. Average illumination in this area is 45 footcandles.

In the balcony, which acts as the choir loft, lighting on the choir pews (located out of sight at the back), ranges from a low of 24 footcandles to a high of 46. The front part of the balcony requires only general illumination since there are no seats here, and the level ranging from 11 footcandles to 18, serves as a transition from the high levels at the back of the balcony and the subdued level in the nave proper.

Lighting for the nave presented the greatest challenge. The modern treatment of the entire church dictated a modern concept in the lighting also. Recessing of any equipment was out because of the construction of the roof; downlighting was impossible. Very satisfactory functional lighting of some 22 footcandles is provided by the factory-fabricated two-lamp cove lighting, which also serves as a decorative element in keeping with the modern lines of the interior. The lower cove is located at the point where the sloping ceiling joins the wall, and a second cove is located at the base of the windows directly under the window openers. Due to the sharp slope of the ceiling directly over the lover cove, and the fact that the upper ceiling is 36 feet wide, impromptu changes were made by the engineer in the standard equipment. Instead of the lamps supplied, reflector type slimline lamps were used in this cove so that the built-in reflector would direct the light along the sloping ceiling rather than cause hot spots directly over the cove. In the upper cove, the lamps were turned at different angles, thereby giving maximum spread and coverage. The white plaster of this surface partially accounts for the high footcandle levels near the side walls. When funds allow, however, it is expected that these surfaces will be painted (talk is, to a dark red), which may affect the levels now obtained.

Lighting design is by Ora L. Apple, Consulting Engineer, Toledo, Ohio, and E. H. Unruh, Day-Brite Lighting Inc., representative, also of Toledo. It was awarded second prize in the 1958 MMILJ contest conducted by the Northwestern Ohio Section of IES.

Restaurant area at Henn's. Outdoor lighting highlights plantings.

Restaurant

Pleasantness of environment — one of the main goals in restaurant lighting — is achieved at Henn's Coffee Shop and Restaurant, Los Angeles, in part through the use of balanced brightnesses. Illumination is provided in the restaurant area by enclosing globes suspended on white plastic covered wire, using 100-watt soft pink lamps. Fixtures are white and white with red stripes, and are enclosed in decorative mesh. Over the back bar behind the counter area, recessed cans use 150-watt floods. PAR38 pink and amber floods in adjustable weatherproof sockets highlight the outdoor planter and walls.

Illumination Levels Footcandles		Brightnesses Footlamberts	
Counter-top	20-22	Counter	19
Table top	8-10	Tables	11
Back bar	40-45	Wall under mural	8
Cooking area	40-48	Floor	5
Entry	10	Enclosing globes	73 (Max)

This installation won third prize in the Southern California Section's contest for My Most Interesting Lighting Job. Lighting designed by Harold I. Strahn, Department of Water and Power, Los Angeles, Calif.

Counter area at Henn's. Not shown is kitchen, using standard cool white slimline lamps.

"Live" studio
WPST-TV
Miami, Fla.

Television Studio

After seven months of operation, the lighting installation in the studio of WPST-TV Miami, Florida, had proved to accomplish its two-fold purpose: To reduce studio lighting to a minimum of time and effort and to improve lighting results by enabling lights to be placed precisely where required.

The live production studio is 52 by 80 feet with a 22-foot-high ceiling. A curved glass window, 30 feet wide, allows pedestrians outside to observe the studio activities. Production control is handled from a booth on the second floor overlooking the studio.

A flexible grid system of channel rails is used to support the lighting units. One 12-foot and 25 20-foot "A" rails form the basic grid. These run the short way of the studio approximately 6 feet on center. They are 14 feet above the floor.

Attached to the "A" rails with double carriers are 44 10-foot-long Group "B" rails. Carriers roll along both the "A" and "B" rails enabling the "B" rails to be positioned and angled so that a light can be located practically any place desired. Each light is attached with a single carrier to either an "A" or a "B" rail, and has an automatic brake to prevent any accidental movement of the equipment. A pole is used to release the brake and move the lights and "B" rails.

Back lights. Normally mounted on the "B" rails which are over the rear of each set, 6-inch Fresnel lens units use 500-watt lamps.

Base and fill lights. Eighteen-inch scoops, with 1000-watt inside frosted lamps and spun glass diffusers are mounted on counter-balanced supports and single carriers. The supports enable each scoop to be elevated to the height required. When not in use, they can be easily pushed up out of the way. As the scoops are on carriers, they can be rolled to the exact locations needed.

Key and special lights. Eight-inch Fresnel lens units are used with 1000-watt lamps. Follow spots with 500-watt lamps are also provided. Each unit is mounted on a single carrier.

Outlets. To minimize the use of long extension cables which require considerable time to handle, an adequate quantity of pigtail outlets is provided. Each of the "A" rails includes an outlet strip composed of raceway with six 20-ampere outlets spaced along the 20-foot rail. To provide for the future use of live color television, each of these outlet strips also has a 50-ampere pigtail outlet located at the center. This totals 156 20-ampere and 26 50-ampere outlets spaced around the studio grid. There are also 10 wall outlet boxes, each with one 20-ampere and one 50-ampere pigtail outlet.

Lighting controls. Since simplified lighting control was desired for normal operation and more complex lighting would be desired for more elaborate shows, a dual control station was designed. The lights for normal shows can be preset so that the director can control them for each show with a minimum of effort. The console contains 12 50-ampere no-dim control circuits and 12 6000-watt interlocking dimmer control circuits. Each of these 24 circuits feeds six jacks so that up to a total of 72 lights on constant voltage and 72 on dimmer

control can be used at any one time. The lights are connected to the 24 circuits with a retractable cord and plug which is inserted into one of the jacks of the control circuit desired. All the lights which are being used at any one time, therefore, can be grouped to a single control switch and handled either by the director or at the studio console. Each one of these load cords includes a quiet acting circuit breaker which also serves as a switch so that control is maintained over each individual light.

Once the lights are set for routine shows, they are controlled by the director at his desk in the production control booth. The director's lighting control is a small panel, 1 by 20 by 6 inches, located on the console along with the camera switching. A pilot light for each control circuit indicates exactly the status of each of the light groups.

This installation won second prize in the Southeast Florida Section's 1958 contest for My Most Interesting Lighting Job. Lighting designed by George Gill, Southern Branch Manager, Century Lighting Inc., North Miami, Florida.

Bus Terminal

In moving their offices and shops to a new location, the Transit Authority of Nashville, Tenn., was presented with the problem of providing an economical lighting system for the maintenance, parking and shop requirements plus street lighting for the incoming, interchange and exiting buses. Heavy pedestrian traffic increased the illumination level needed.

There are two parking areas at different levels, for buses, a concentrated servicing area, visitors' parking, and two main streets with ramps leading to the other locations. Street lighting units were chosen for the entire installation to simplify maintenance. A total of 26 400-watt H1LS 20,000-lumen mercury lamps are used in 22 Type III and 4 Type II units, mounted at 30 feet on a 6-foot arm.

Servicing area — 5 footcandles, at Nashville Transit Authority bus terminal.

In addition, three larger units with 1000-watt, 52,000-lumen lamps are used in the lower level parking area for buses. Except around the office building where aluminum standards are used for esthetic reasons, the luminaires are mounted on wooden poles.

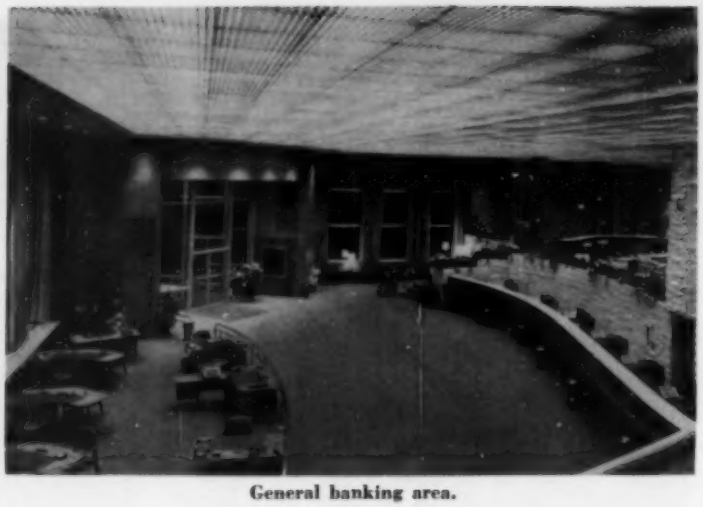
Lighting units are located around the perimeter of the parking areas and adjacent to the servicing and maintenance area. This provides adequate parking illumination and also serves as silhouette lighting. Calculated average in-service illumination for the entire area is 1.5 footcandles. Measured levels after a year's operation were between 2½ and 3 footcandles on streets and ramps and 5 footcandles in the bus servicing areas.

This installation won first prize in the Tennessee Valley Section's 1958 contest for MMILJ. Lighting designed by William H. Ridley, Lighting Engineer, Nashville Electric Service, Nashville, Tenn.

"An Island of Light" — Nashville Transit Authority bus terminal.

Modern thinking,
Modern design
for a

New Bank Building



General banking area.

COMPLETE departure from the traditional regularity of design for banks was the desire of the officials of the two banks which merged into the Citizen's Bank of Sheboygan, Wis. In deciding upon a new building to house the combined facilities, they specifically requested the cordial atmosphere which is part of today's policy in banks' public relations.

The most obvious features of the architecture are the sweeping curves of counters, railings and stairways leading from one department to another. A louverall ceiling, of 2- by 2-inch steel cells supplements this impression of unity, and provides 50 footcandles general illumination. The ceiling is sprayed in varying shades of warm gold, to avoid monotony.

Curving walls in the bookkeeping department presented a problem in providing a suitable lighting design. This was solved by installing a pattern of two-lamp troffers, with low brightness glass diffusers, which follows the curvature of the room. Illumination level is 95 footcandles on the working plane.

The Savings and Loan Department is located under a balcony and uses recessed luminaires, four feet in diameter, with plastic diffusers. Levels here are around 75 footcandles. Luminaires follow the curves of counters and exterior walls.

Extensive use of plantings and warm-toned stone add to the over-all atmosphere of cordial welcome and concern for the comfort of the customer.

Lighting designed by Trester Engineering Co. of Sheboygan and Milwaukee, Wis. This installation won first prize for the company's branch manager, James Lutz, in the Milwaukee Section's 1958 contest for My Most Interesting Lighting Job.

Bookkeeping department.

Savings and loan department.

Design and Evaluation of

High Utilization Fluorescent Street Lighting Luminaire

By D. E. HUSBY

THE INTRODUCTION and use of fluorescent lighting on streets and highways during the past five to six years has been made using luminaire design concepts dictated basically by the shape of the lamp and its associated ballasts. The optical design of these luminaires has been elementary, in that the lamp was placed so that its length was normal to the flow of traffic, thus placing the lamp's maximum candlepower output generally in line with the flow of traffic. To further aid this apportioning of the lamp's output, a contoured reflector, generally parabolic in cross section, was placed on one side of the lamp. This reflector allowed some degree of directional control of the lamp's output up or down the street in line with traffic flow. This led to the selection of even numbers of lamps per luminaire to provide equal distribution up and down the street.

Since the lumen output of fluorescent lamps is relatively low on a per foot basis, the longer lamps have been used and a multiplicity of lamps has been used to provide the lumen output required for street lighting.

The mechanical construction of these first designs were predicated on the position of the lamps with reference to the street, the number and lengths of lamps, the size of the associated reflector, and the ballasting equipment. This resulted in luminaires having a long bulky appearance, which, when combined with poles, resemble an up-ended golf club.

Fixed Dimensions in Applying Fluorescent Lighting to Streets

Unlike other light sources used in street lighting, the fluorescent lamp is extremely long in comparison to its cross sectional area. Consequently, the optical design must be different from that which is customarily used with incandescent or mercury lamps. As the cross section of the fluorescent lamp increases from the one-inch diameter of the T-8 lamp to the 2½-inch diameter of the T-17 lamp, different control surfaces are required to effectively control the light from each different cross sectional size. Because of the relatively low brightness of the fluorescent source, a proportionally larger reflector flashed area is required to deliver a candlepower distribution comparable to that from incandescent or mercury.

Very little control of light flux can be accomplished longitudinal of the lamp by means of a reflector, due to the length of the light source. Some attempts have been made to control this longitudinal distribution by tilting the luminaire up or by building it in such a manner as to produce a "V" type luminaire, thus in effect, toeing the beam candlepower into the street area or longitudinally of the lamp. These attempts were either more costly or did not appreciably improve the luminaire's performance.

It would seem logical that longitudinal light control should be by refraction. In the evolutionary development of incandescent street lighting, control by refraction played an important part and in the evolution of mercury vapor type street lights, refractors were used from the start. Fig. 1 indicates, in tabular form, the improvement in incandescent street lighting luminaires as the design evolved into the modern optical system which utilizes both reflector and refractor control. Fig. 2 indicates the relative status of the fluorescent street lighting luminaire as its design evolved toward improved performance. Both reflectors and refractors have advantages and limitations and the optimum is achieved if both are used correctly and in a unified design.

Relation of Application Requirements To Luminaire Design

Since it is necessary to increase the coefficient of utilization curve to increase the level of illumination on a particular roadway using a given lumen output for a luminaire, it follows that an increase

A paper presented at the National Technical Conference of the Illuminating Engineering Society, August 17-22, 1958, Toronto, Ont.
AUTHOR: Lighting Division, Westinghouse Electric Corp., Cleveland, Ohio.
This paper accepted by the Papers Committee of I.E.S. as a Transaction of the Illuminating Engineering Society.

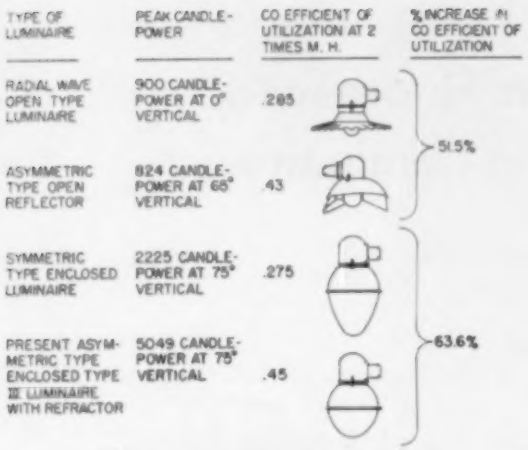


Figure 1. Incandescent luminaires.

of utilization efficiency is required in the street area illuminated by the fluorescent luminaire to justify its worth with respect to other source luminaires. This can only be accomplished by directing the usable light energy from the luminaire into the street area itself.

The increase in utilization efficiency is no more important, however, than the uniformity provided by the luminaire. Good design practice does not permit an increase in utilization efficiency if uniformity is sacrificed. All factors must be considered and compromises made, where necessary, to provide the best utilization, at the highest maintained level, over the greatest area and with a high uniformity of illumination

These factors are at times considered independently and without regard to the resultant brightness of the luminaire to the driver. Hence, the glare presented to the driver is often of such degree

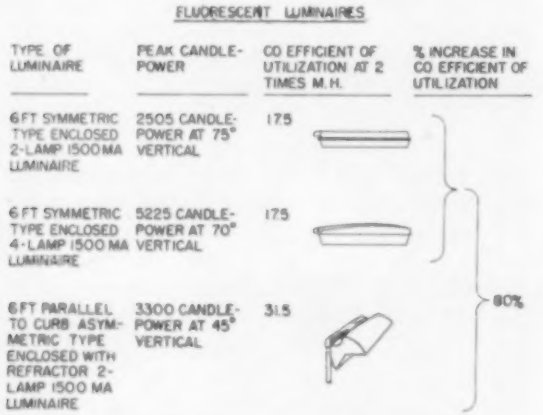

FLUORESCENT LUMINAIRES
TYPE OF LUMINAIRE
PEAK CANDLE-POWER
CO EFFICIENT OF UTILIZATION AT 2 TIMES M.H.
% INCREASE IN CO EFFICIENT OF UTILIZATION
6 FT SYMMETRIC TYPE ENCLOSED 2-LAMP 1500 MA LUMINAIRE
2505 CANDLE-POWER AT 75° VERTICAL
1.75
6 FT SYMMETRIC TYPE ENCLOSED 4-LAMP 1500 MA LUMINAIRE
5225 CANDLE-POWER AT 70° VERTICAL
1.75
6 FT PARALLEL TO CURB ASYM-METRIC TYPE ENCLOSED WITH REFRACTOR 2-LAMP 1500 MA LUMINAIRE
3300 CANDLE-POWER AT 45° VERTICAL
3.15
80%

Figure 2. Fluorescent luminaires.

as to nullify all other creditable features of a luminaire. This becomes particularly offensive with the use of the more highly loaded fluorescent lamps. The fluorescent lamp is basically a low brightness lamp; however, with conventional fluorescent luminaires, this brightness is greatly increased by the addition of a large reflector area flashed by the lamp in a direction longitudinal of the street. This is further emphasized by the lack of any shielding medium to provide a distinct cut-off of beam candlepower, such as is provided in present day incandescent and mercury vapor luminaires.

From the preceding discussion, it can be seen that the normal to traffic flow design of fluorescent street lighting luminaires offers little promise as a design approach to major improvement in utilization factor or comfort. In order to achieve such improvement, it is necessary to follow a different approach which has greater potential.

New Approach to Street Lighting Requirements Using a Fluorescent Source

Recently a new approach has been initiated utilizing fluorescent sources for street lighting. Primarily, this has been the changing of the basic position of the fluorescent lamp with respect to the street. By placing the lamp's length parallel to the roadway, higher street-side utilization is achieved, due to the fact that reflector control is most effective on the smaller cross sectional dimension of the lamp and can limit the lamp's light output to the area to be illuminated.

With the luminaire parallel to the roadway and the output of the lamp being directed by the reflector to provide illumination control normal to the roadway, thus providing high street-side utilization, the longitudinal control cannot be provided by the reflector but can be provided by a refractor. The approach of placing the luminaire parallel to the roadway and controlling the longitudinal distribution by means of a refractor also allows better uniformity with practically no glare to the driver since beam cut-off can be provided along with control, much the same as is found in incandescent and mercury vapor type luminaires.

The method employed in the refractor, to provide beam cut-off above a specified angle, is radically different from the cut-off methods employed in incandescent or mercury vapor luminaires. A graphical illustration of this method is shown in Fig. 3 and illustrates the manner in which prismatic louvers are used to re-direct the high angle light back into the desirable zone. The resultant brightness at high angles, when compared to conventional incandescent and mercury vapor luminaires, is

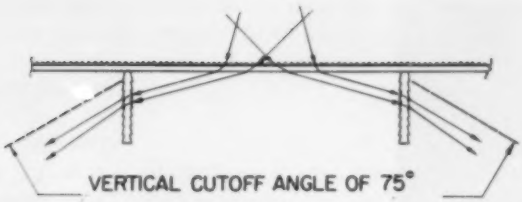


Figure 3. Reflector ray trace of parallel-to-curb fluorescent street light with vertical cut-off angle of 75 degrees provided by prismatic louvers.

markedly reduced to provide a new level of comfort since the longitudinal or end brightness possible with this approach is much lower than the resultant brightness of the conventional incandescent or mercury source luminaire.

This glare or luminaire brightness presented to the motorist has become one of great concern to those interested in the comfort of street lighting. It seems that as higher levels of illumination are required and provided for streets and roadways, less and less comfort is provided for the motorist. This is a very dangerous pattern to follow because it approaches a condition where so much glare is present, disadvantages of reduced visibility more than offset the advantages of the higher illumination levels.

It appears that the most important factor in improvement of street lighting now should be providing comfortable "seeability." If no improvement other than the elimination of this offensive luminaire brightness could be made, it is felt that a major advance would be made in street lighting. It is in this area that a luminaire design which places the lamp, and therefore its highest candlepower, parallel to the roadway could make its major contribution to the street lighting art. Another basic failing of the transverse distribution and high brightness is its inapplicability to wide streets, since the end brightness of the lamp is inherently low. Invariably, the illumination on the area directly across the street from the transverse type fluorescent luminaire is poor and must be supported by opposite spacing of luminaires on most relatively wide streets. By adopting a parallel type luminaire, good distribution across the street is provided so that streets may be lighted with a high degree of uniformity.

Effects of Parallel Optical Approach To Appearance and Mechanical Construction

Other benefits derived from the use of a parallel-to-the-roadway optical approach are also important. It is noted that the conventional transverse type luminaire cannot be close coupled to the pole but locates the luminaire center of gravity several feet from the pole. By mounting the luminaire parallel to the roadway, its center of gravity may be located very close to the pole. This close coupling to the pole allows a much more stable mechanical construction than does the conventional transverse type of luminaire. Mechanically, the unit can be made stronger. The windage area can be reduced and also more equally balanced, thus reducing the stresses presented to the supporting pole.

Due to the present optical approaches used in the transverse type luminaire, the day-time appearance of these fixtures is objectional to many peo-

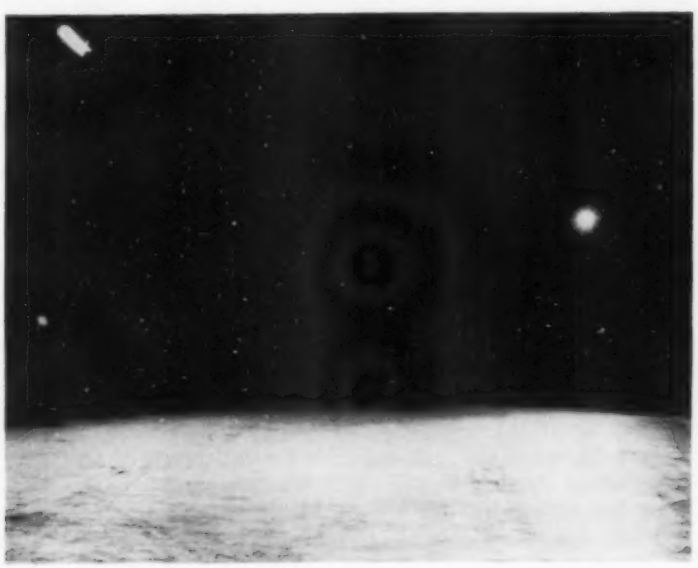


Figure 4. Photograph of test street.

Figure 5. Photograph of test street.

ple. There is reason to believe that the parallel approach will be much more acceptable since the projected area presented to the driving public is sharply reduced. At night, these luminaires appear to outline the roadway limits and to define the direction of the roadway.

The veiling brightness is markedly reduced by adopting the parallel-to-the-roadway approach indicated by Fig. 4. This photograph shows a parallel-to-the-roadway fluorescent luminaire with a refractor and a conventional mercury vapor luminaire. The great difference in veiling brightness is indicated by the detail present in the parallel mounted fluorescent luminaire compared to the mercury vapor luminaire shown on the opposite side of the photograph. It is interesting to note that the bright spot below the fluorescent luminaire is evidence of a conventional type incandescent street light mounted approximately 600 feet behind this test installation.

A test installation is shown in Fig. 5. This photograph is of three parallel-to-the-roadway fluorescent luminaires mounted on 100-foot staggered centers. The street width is 60 feet, mounting height is approximately 33 feet. This shows that uniform lighting can be accomplished with a minimum of luminaire brightness, using a fluorescent source.

Keeping in mind the great advances made in fluorescent lamp technology and further expected refinements, it can only be assumed that the fluorescent street light will eventually be preferred to incandescent and mercury vapor even without an evaluation of the improved comfort level. Even now, as illustrated in Table I, the operating economies on a lumen per watt basis for a parallel-to-the-roadway luminaire with refractor compares very favorably with the present highly efficient mercury vapor luminaire. As compared to the conventional transverse fluorescent luminaire, both using the high output (1500 ma) lamps, it is seen that the lumens per watt delivered to a roadway, where street width equals twice the mounting height, is nearly doubled by adopting this new approach.

It should be re-emphasized that this approach yields a luminaire which gives a new level of comfort which, in the opinion of many observers, cannot be matched by any other design approach on the market today. This new level of comfort is provided by the use of prismatic control, as well as by the parallel mounting of the fixture. Without the refractor, the great reduction of veiling brightness cannot be achieved. This is primarily true because there is no effective method of properly providing sharp cut-off of the beam candlepower, except by refraction, due to the inherently large lamp dimension to be controlled.

If the refractor is not used for optical control and vertical cut-off, the approach to parallel mounting of luminaires to the roadway results in just another poor substitute for good street lighting. The progress in refinement of fluorescent street lighting using this new approach can be compared to that progressive step which occurred in

TABLE I — Operating Economies of Source Luminaires.

Comparison of Lumens on Street Per Lamp Watt (Street Width = 2 times Mounting Height).	Lumens Per Watt
Parallel to curb luminaire with two highly loaded lamps at 75 F	19 lumens/watt
4-lamp conventional transverse luminaire with four highly loaded lamps at 75 F	10.2 lumens/watt
400-watt improved-color mercury vapor luminaire with J-H1 lamp	21 lumens/watt
400-watt clear mercury vapor luminaire with E-H1 lamp	24 lumens/watt
Incandescent luminaire with incandescent lamp	6.3 lumens/watt

incandescent street lighting when the designs went from the radial wave type to the refractor type, to obtain better street-side utilization and controlled distribution.

Conclusions

The design approach which provides a fluorescent street light, with a refractor, parallel to the roadway is a major step taken in the direction of providing fluorescent lighting of streets at a utilization of light level which is now enjoyed by incandescent and mercury vapor street lighting. This new approach has improved the design concepts of fluorescent street lighting in as great a measure as street lighting itself was improved by the introduction of mercury vapor street lighting.

Advantages of the parallel-to-curb-approach are:

(1) Major improvement in the coefficient of utilization,

(2) Improved uniformity of illumination,

(3) Radical reduction in luminaire brightness at high angles resulting in much more comfortable lighting,

(4) Improved daytime appearance,

(5) Reduction in pole stress due to balanced wind loading and center of gravity close to pole.

Disadvantages of the parallel-to-curb-approach are:

(1) Reflector enclosed lamp more completely reducing total efficiency. This is more than offset by advantage No. 1,

(2) Reduction in size of reflected image on wet pavements,

(3) Limitation (under present luminaire design) of the vertical angle of maximum candlepower resulting in a maximum spacing to mounting height ratio of 3:1.

It is the author's opinion that a continuous line of light along each curb represents an idealized goal but the economics of the situation do not permit its general usage. A more realistic approach is the one outlined in this paper.

DISCUSSION

G. E. KORTEN:* Early last June, a group of us visited Bellefontaine, Ohio to see the new street lighting installation described in this paper. This new type of luminaire does improve the street lighting; however, several of the utility men in our group felt that probably from 25-30 per cent more luminaires should have been used to light the same area. In other words, we would have recommended closer spacing of luminaires in the business area.

Several of our group talked to various local people and there seemed to be a general feeling that many of the people liked the new adjacent 20,000-lumen mercury luminaire better than the new fluorescent system. We engineers may agree that this new type of fluorescent unit gives better lighting on the roadway, but the people who are paying the bill still like to see some form of light source, especially in business areas.

It is suggested that the information in Table I be expanded to include system cost studies. In the past few years papers presented at the Society's National Technical Conferences have seemed to give the impression that fluorescent street lighting is more expensive than street lighting from other light sources.

K. D. TOBIN:* The author and his associates are to be commended for their efforts to improve the performance quality of the lighting equipment offered to the street lighting industry. It is indeed refreshing to see developments of this type being proposed. I can only hope that what has been learned from this development will be a stepping stone to greater improvements in fluorescent street lighting equipment of all manufacturers.

Our tests and visual appraisals of luminaires of this type show that *without a refractor* and the same geometric configuration used in the paper:

(1) Average footcandle levels are as much as 30 per cent higher;

(2) Average to minimum ratios are in the order of 2½:1 as compared to 3½:1 with a refractor;

(3) 3:1 spacing to mounting height ratios are too long with parallel positioned units, resulting in a very spotty pavement brightness uniformity pattern. 2:1 appears to be the maximum satisfactory spacing.

In addition to these points, the apparent lack of illumination resulting from turning the main distribution 90 degrees from the observer's viewing position and making visible only a relatively small "source" gives a "tunnel effect" which apparently causes a psychological feeling of inadequate illumination. This appears to be true even though average horizontal footcandles are in accord with recognized standards.

The biggest single advantage to fluorescent street lighting is the long low brightness source mounted transverse to the roadway which results in broad bands of pavement brightness particularly on wet pavement where seeing conditions are most unfavorable. Turning the units parallel to the curbline causes this advantage to diminish. Loss of pavement brightness and uniformity are critical with average illumination levels in use today — 1-2 footcandles or less. Higher illumination levels may, of course, not require the same degree of control for obvious reasons. However, the higher levels quite conceivably could require pole spacings in the order of 50 feet or less, which means a relatively high structure cost and therefore a lower economic value of the lighting system.

I believe an alternate answer to the higher level jobs is the system of "Tee Lighting" which utilizes a standard unit mounted in the normal position and providing good pavement brightness uniformity and a pleasing appearance. Add to this parallel lights for increased average illumination.

There certainly can be no argument concerning the ultimate system of continuous lighting parallel to the roadway. The superior comfort and quality of this type of system has already been demonstrated by Mr. Nonneman of the Dayton Power and Light Co. and at the "Crossroads of Light" in Hendersonville, N. C. Until a practical economical answer is found to this high quality continuous system, however, I feel there is more lost than gained by turning a single unit

*Consumers Power Co., Jackson, Mich.

*Outdoor Lighting Dept., General Electric Co., Hendersonville, N. C.

per pole parallel to the movement of traffic — with or without present day refractors. As the state of the art progresses, however, I am hopeful that performance characteristics can be improved to make the economics of the system more attractive.

D. E. HUSBY:* The indications of preference for mercury over the new approach type of luminaire are expressions of cultivated opinion. So much emphasis has been placed on "brightness" that the layman assumes that if glare is increased, the unit is better. I feel that if a person were asked to compare units for comfort or to pick the type of unit most desirable to drive under from a comfort and illumination standpoint, there would be no doubt as to which type of unit would be picked.

The lack of the "broad bands of pavement brightness" cannot be classed as critical, since the normal case of observation and application is in an area of traffic density such that little or none of the pavement is observed. For obvious reasons, to the contrary, direct illumination is, of necessity, without the offending impingement of source brightness. This brightness only serves to reduce the useful illumination provided for the road area by modern design, whether such reduction is made inherently by the luminaire itself or by the addition of a unit normal to the roadway, thus contributing the subtraction brightness at increased user cost.

Speaking briefly of cost, it is doubtful that any system can be devised, using present day luminaires, which will show fluorescent street lighting luminaires to be less expensive, system for system, than other sources, such as mercury vapor. The use of fluorescent sources for roadway lighting must be compared to other fluorescent sources, due to the fact that the fluorescent luminaire of today is by its very nature expensive.

However, cost is not the feature being dealt with directly here. The subject under discussion is a concept of design which increases the comfort and utilization of fluorescent street lighting luminaires. The cost illustrations in the paper were illustrative devices used for comparison of units of various design concepts, employing a basic denominator.

In summation, it does not appear that there is a difference of opinion as far as the ultimate system of "continuous lighting parallel to the roadway" is concerned, rather to what extent that system is practical or attainable. The system design with refractive and reflective control obviously provides the greatest possible means of achieving the closest realistic approach to this optimum end.

*Author.

Floodlighting with Streetlights

Horizontal burning mercury vapor street lighting luminaires projected four feet in front of the building facade are used to floodlight the Jefferson County Savings Bank in Watertown, N. Y. In this unusual application of street lighting luminaires, the glassware of the fixtures is reversed to project the beam pattern across the face of the building, with maximum intensity directed at the base of the columns. Six luminaires, mounted on 10-foot centers, are equipped with 400-watt improved-color mercury vapor lamps rated at 20,000 lumens and having a life of 7000 hours.

Measured vertical illumination at the base of the columns is 8 footcandles, estimated illumination across the column tops is 20-30 footcandles.

Maintenance of the lighting system is simple, due to the long life of the lamps and to a specially designed swing bracket arrangement for relamping.

With this new floodlighting system, the Jefferson County Bank, located at the edge of the Watertown business district, stands out in dramatic contrast to its dimly-lit surroundings.

R. H. Rice, Westinghouse Electric Corp., Albany, N. Y., won second prize in the Eastern New York Section's 1958 MMILJ contest with this installation.

A Demonstration Laboratory For Roadway Lighting

By R. M. SWETLAND
K. D. TOBIN

I. Introduction

A. Need for Such a Facility

The roadway lighting industry in this country has long recognized the need for comprehensive, full-scale outdoor demonstration and research laboratories of the inclusive type now found at Hendersonville, in western North Carolina.

Laboratory photometric tests of luminaires, average illumination (footcandles) and brightness (footlamberts) calculations on the roadway, luminaire glare and discomfort instrument measurements and calculations, while useful in evaluating and appraising the components relative to roadway visibility and comfort, are finally, however, inadequate in forming the most accurate and complete appraisal. The over-all lighting results must be seen under full-scale realistic conditions to be of greatest value.

"To see is to believe," to appreciate and to understand. Such visual appraising is of particular value to laymen, who may not be too familiar with the technical factors and components involved in roadway seeing. Furthermore, a visual inspection of various roadway lighting systems enables a more conclusive opinion on the effect of color of the illuminant on resulting visibility and comfort under all pavement and weather conditions. Thus, with the increasing emphasis, locally and nationally, given to both urban and inter-urban roadway lighting, such outdoor full-scale demonstration "test tracks" and research areas appear indispensable to the achievement of most effective night roadway seeing.

B. More Specific Advantages and Objectives

A brief summary, here, of the chief benefits from this full-scale demonstration facility may be of value.

(1) From only one central viewing point, a full range of IES Code advised illumination levels, under three different illuminants applied to various street widths, can be observed and evaluated.

(2) Time and expense of visiting numerous widely-scattered installations and areas is reduced.

(3) Instant switching of the three alternate illuminants — filament, mercury and fluorescent — is possible.

(4) Appraisal of the influence of concrete *vs* asphalt paving material on the over-all visibility is possible.

(5) Effective experimentation with new luminaire designs and application techniques is possible.

(6) An opportunity is afforded for further instrument exploration of various roadway seeing factors.

II. Description of the Installation And Equipment Involved

A. Street Layout, and Pavement Types

Fig. 1 shows a plot plan of the four street sections, extending from a central viewing point intersection. The retail business and "white-way" sections are 70 feet wide; half the width being concrete, the other half asphalt. Fig. 2 shows the retail business section. Measured reflectance of concrete, 32 per cent; asphalt, 9.5 per cent. The arterial section is 50 feet wide. When completed, half the width will be concrete, the other half asphalt. The residential leg is 25 feet wide. Half the length (full width) will be concrete; the other half, asphalt.

B. Luminaires and Lamps

A total of approximately 140 luminaires are

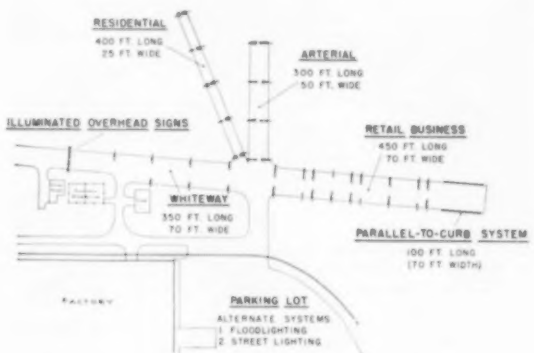


Figure 1. Plot plan of demonstration streets.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, August 17-22, 1958, Toronto, Ont.
Authors: General Electric Co., Outdoor Lighting Department, Hendersonville, N. C.

Figure 2. Day view of 70-foot wide retail business section.

involved in the overhead lighting system. All five IES light control patterns prevail,[1] plus several modified patterns.

Filament, mercury and fluorescent light sources, of various sizes, light output ratings and color quality, are displayed.

C. Supporting Poles

A total of 49 poles are used, several of these poles supporting three types of luminaires, as shown by Figs. 2 and 7. Four general types of poles are installed, namely, steel, aluminum, concrete, and wood.

Table I lists luminaire mounting heights.

D. Range in Average Footcandle Levels

As indicated in Table I, a wide range of illumination on the roadways, from approximately 0.1 footcandle to over 6.0 footcandles, is afforded from a single given luminaire arrangement. (A higher level, of approximately 10 footcandles, can be obtained by superimposing two circuits on the "whiteway" section.)

E. Total Generated Light, and Connected Load

The total rated light output of all lamps involved in this installation is approximately 2,250,-

TABLE I — Luminaire Spacings, Lamp Sizes and Calculated Average Initial Footcandles.

1. Residential Section (25-foot width) — See Fig. 4

	100 feet 1 side	200 feet 1 side
1. Open Reflector (Type II) 2500-lumen — Filament	0.37 fc	0.18 fc
2. Open Reflector (Type II) 3500-lumen — Mercury	0.45 fc	0.23 fc
3. Enclosed Refractor (Type I) 6000-lumen — Filament		0.3 fc
4. Fluorescent, 4-foot, 2-lamp (I wide' 7200-lumen (HO)	0.45 fc	0.22 fc
5. Fluorescent, 2-foot, 2-lamp (I wide) 2880-lumen (HO)	0.2 fc	0.1 fc
*6. Open symmetrical reflector (Type V) 2500-lumen — Filament		0.12 fc

*For comparison. Not generally recommended.

Note: (a) Mounting heights: Open reflector units — 24 to 25 feet; fluorescent — 26 to 28 feet; 6000-lumen filament — 27 feet.

2. Arterial Section (50-foot width) — See Fig. 5

	100 feet Staggered
1. Enclosed Refractor (Type IV) 20,000-lumen — Improevd-color mercury	1.6 fc
2. Enclosed Refractor (Type IV) 23,000-lumen — White Mercury	1.7 fc
3. Enclosed Refractor (Type III) 11,000-lumen — Mercury	1.14 fc
4. Enclosed Refractor (Type III) 15,000-lumen — Filament	1.55 fc
5. Enclosed Refractor (Type III) 10,000-lumen — Filament	0.9 fc
6. Fluorescent, 6-foot, 4-lamp (Type I) 23,000-lumen (HO)	1.15 fc
7. Fluorescent, 6-foot, 2-lamp (Type I) 11,500-lumen (HO)	0.6 fc

Note: (a) Mounting heights: Fluorescent and 10,000-lumen filament — 28 feet; E-1 mercury and 15,000-lumen filament — 30 feet; 11,000-lumen mercury — 27 feet.

3. Retail Business Section (70-foot width) — See Fig. 6

	100 feet Opposite	100 feet Staggered
*1. Enclosed Refractor (Type III) 15,000-lumen — Filament	2.5 fc	1.25 fc
*2. Enclosed Refractor (Type III) 21,000-lumen — Mercury	3.2 fc	1.6 fc
**3. Fluorescent, 6-foot, 4-lamp (Type I) 23,000-lumen (HO)	1.65 fc	0.83 fc

*Also at 75 feet, staggered.

**Also at 75 feet, opposite and staggered.

Note: (a) Mounting heights: Mercury — 32 feet; filament — 30 feet; fluorescent — 28 feet.

4. White-Way Section (70-foot width) — See Fig. 7

	100 feet Opposite	100 feet Staggered
1. Mercury Enclosed Refractor (Type IV) A-15, 54,000-lumen	6.6 fc	3.3 fc
2. Fluorescent, 6-foot, 6-lamp (PG) (Type I) 55,800-lumen	3.6 fc	1.8 fc

Note: Mounting heights: Mercury — 34 feet; fluorescent — 31 feet.

Comments

In actual roadway lighting design the I.E.S. Roadway Lighting Committee urges the use of proper depreciation factors, resulting in maintained footcandle levels.

Luminaire overhang distances range from 3 to 9 feet.

Fluorescent calculations based on 50 F ambient temperature.

Figure 3. Night panorama of the outdoor roadway lighting facility, "Crossroads of Light."

Figure 4. Residential section, lighted by 6000-lumen filament lamps on 200-foot spacing.

Figure 5. Arterial section, lighted by 400-watt E-H1 and J-H1 mercury lamps, 100-foot staggered.

Figure 6. Retail business section, lighted by 4-lamp (HO) 6-foot fluorescent units, 100-foot linear and opposite.

Figure 7. "White-way" section, lighted by 1000-watt, A-15 mercury lamps. 100-foot linear and opposite.

Figure 8. Control console at street intersection — with authors.

000 lumens. Fig. 3 shows a partial panorama of this "Crossroads of Light." The total connected load is approximately 70 kva.

F. Circuits and Control

The need for supplying power to approximately 140 luminaires on some 49 poles, in a total of 36 luminaire and spacing combinations, with provision for circuit expansion and growth for new developments, introduced a most interesting problem.

A three-wire, 120/240-volt single phase circuit was extended from the main plant substation to each pole, consisting, basically, of two primary legs of 37.5 kva capacity each. Overlapping the power supply is a 120-volt control circuit operated from a control console at the central Crossroads intersection (see Fig. 8). Thus, there is a console control switch for each of the 36 luminaire and spacing combinations which energizes the proper power relays in weatherproof boxes on each pole.

Fusing for both power and control leads is located at each pole. Thus, not only is the desirable protection afforded, but also there is added flexibility for possible "omitting" of certain luminaires in any given combination.

All wiring for power and control is direct burial underground cable. The residential section is an exception, having wood poles carrying overhead wiring, to simulate majority conditions incident to such streets.

An additional constant current series circuit is available to energize permanent entrance-way lighting to the parking lot and service areas.

III. Experimental and Research Modifications

A. Continuous-Line Parallel-to-Curb Lighting

Typical of the experimental projects being investigated is this overhead line-of-light above each curb, along a 100-foot length of the 70-foot wide section (see Fig. 9). The high-output, 8-foot, T-12 fluorescent lamp is used in enclosed single-lamp units. There are 12 luminaires along each side. A steel catenary supports the units and ballasts.

Approximately seven footcandles average over the entire pavement results. With all lamps energized, light distribution and pavement brightness uniformity is excellent. Alternate lamps can be switched off, and also, lamps along only *one* side can be energized. Luminaire brightness is minimized by this type of lighting system.

B. Low-Mounted Parapet Sources

Fig. 10 illustrates the attention being given to effective lighting of a roadway from such low-mounted sources.

In this investigation, 6-foot fluorescent luminaires equipped with T-12 high output lamps in enclosed shielding-type fixtures, are arranged along one side of the pavement on approximately 12-foot

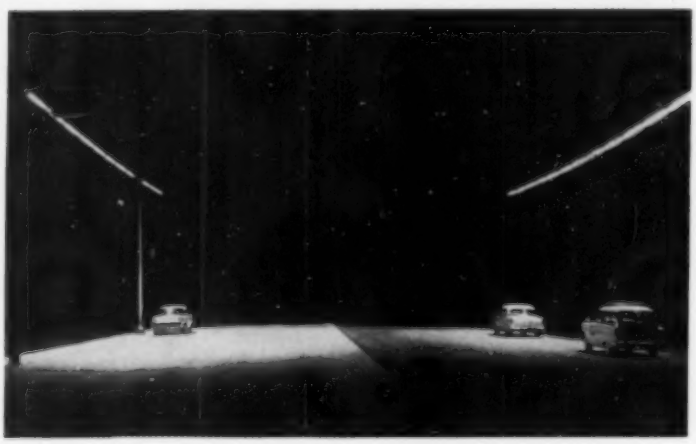


Figure 9. Continuous-line system using enclosed units and 8-foot high-output fluorescent lamps.

Figure 10. Low mounted (parapet) system with 6-foot, high-output fluorescent lamps on 12-foot centers.

centers. Various light control patterns and linear spacings are being studied.

C. "Tee" Lighting Arrangement

Another luminaire mounting arrangement being studied is the "Tee" pattern, with three fluorescent luminaires per pole, as illustrated by Fig. 11.

Two luminaires are arranged parallel to the curb, with the third at right angles to the curb line. Such an arrangement seems particularly advantageous for higher-level, wide, retail business streets. The increased light output per pole promotes desirable economy. The parallel alignment of two luminaires reduces projected globe area brightness toward vehicular traffic. Many observers believe it produces more comfortable seeing.

Figure 11. "Tee" arrangement of fluorescent luminaires. Two units parallel to curb.

D. Discomfort Glare Studies

Fig. 12 shows roadway seeing research being conducted, using the Guth Discomfort Glare Evaluator. Thus, a more accurate field appraisal is possible of the relative discomfort of various lighting systems, and in relation to various types of pavement surfaces.

E. Highway Sign Illumination

Effective lighting of highway signs is also being studied. Fig. 13 illustrates this objective, showing 6-foot by 12-foot signs (both painted and reflectorized) lighted to a 40-footcandle average level by enclosed fluorescent-lamp units along both top and bottom edges. (The top and bottom luminaires can be switched separately.)

F. Automobile Parking Area Lighting

A parking lot, immediately adjacent to this "Crossroads of Light" installation, will be effectively lighted by two alternate methods, switched separately for evaluating over-all resulting visibility.

(1) *Floodlighting* — Both incandescent and mercury floodlights, supported on three 60-foot steel poles, are being used. Circuit arrangement is such as to result in illumination levels of from 0.5 to 2.0 footcandles.

(2) *Street Lighting Treatment* — Here, fluorescent luminaires of the 4-lamp 6-foot size, twin-mounted on ten metal poles, will be used. A mounting height of approximately 32 feet is afforded. Here again, circuit arrangement, plus the probable use of both high output and power groove sources, will assure a flexibility of 0.5 to 2.0 footcandles over the area.

Figure 12. Guth Discomfort Glare Evaluator used in rating relative discomfort of roadway lighting systems.

G. Pavement Reflectance Improvement

Two areas along the concrete portion of the pavement have been treated (sprayed) with a water-soluble silicone solution. Somewhat in the nature of a by-product benefit, this water-repellent treatment increases the diffuse reflection of wet pavement to approximately that of dry pavement conditions — an increase of about 55 per cent.

This present type of silicone solution is not suitable for asphalt pavement application.

H. Roadway Visibility in Fog

Recent investigations, under the sponsorship of the IES Research Institute,[2] reveal the desirability of projecting light more nearly at right angles to the line of sight for improved visibility under dense fog conditions. The experimental systems outlined previously, under subheadings A and B appear to lend themselves quite effectively to further study from this fog standpoint.

I. Automobile Headlights and Overhead Fixed Lighting

This full-scale demonstration facility affords an effective setting for observing the roadway seeing relationship between automobile headlamps alone, and these same lamps in conjunction with various overhead lighting systems. To many visitors this particular demonstration effectively emphasizes the value of an overhead lighting system, especially to assure maximum protection to pedestrian traffic along urban streets.

IV. Comments on First Full Year Of Operating This Facility

A. Visitors

Some 65 separate groups, totaling approximately 1100 individuals, inspected this facility during the year. A majority of these were either directly or indirectly connected with roadway lighting projects in this country. Several were from outside the United States.

All were most favorably impressed. They were better informed on roadway lighting practice and seeing fundamentals, upon leaving. Many remarks were volunteered, such as: "This is the way our street back home should be lighted."

B. Color of Light and Resulting Seeing

Much interest was evidenced in appraising overall visibility and seeing both under illuminants giving true color appearance of objects and people, and under those causing some distortion of true color appearance. Visitors' opinion polls indicated more than 60 per cent favored true-color producing illuminants on a basis of approximate equality in average illumination.

C. Discomfort Glare Studies

Insufficient data have been obtained, to date, to

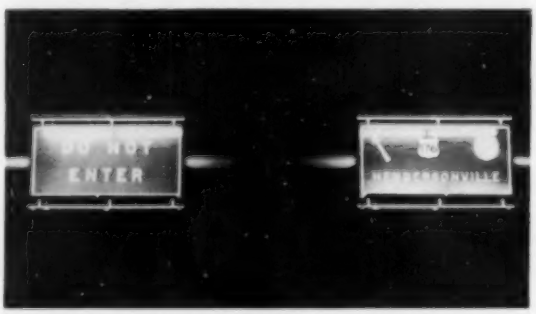


Figure 13. Highway signs lighted to a 40-footcandle level by fluorescent lamps.

warrant any meaningful statement of results. These investigations are being continued.

D. Luminaire Light Control Appraisals

Valuable information is being obtained on this vital phase of roadway lighting practice. A better understanding of the relationship between "what the laboratory photometer sees and what the eye sees" is being crystalized. All this information aids the design and application of "better luminaire for better roadway seeing."

V. Conclusion

While this "Crossroads of Light" demonstration and research facility is by no means the first of its kind in this country,[3] there is good reason to believe that it is the most inclusive in scope, and the most flexible in operation, of any such installation to date.

Not the least of the already-realized, as well as expected, benefits from this facility is the example and encouragement given to progressive electric utilities (and to other major agencies engaged in sponsoring, selling or installing roadway lighting) to plan and to install their own roadway lighting demonstration streets. Already, a few utilities have invested in such projects. Desirable dividends, in terms of a better appreciation of and desire for improved protective roadway visibility in their areas, are being realized.

All who are interested in promoting and acquiring better roadway lighting are urged to visit this Hendersonville facility. The "Crossroads of Light" already has proved helpful in achieving improved night safety and comfort, with economy, on our urban and interurban roadways.

References

1. "American Standard Practice for Street and Highway Lighting," Illuminating Engineering Society, New York, N. Y.
2. Marsh, Charles: "Highway Visibility in Fog," Illuminating Engineering, Vol. LII, No. 12, p. 621 (December 1957).
3. Nagel, George A.: "A Highway Lighting Test Installation," Illuminating Engineering, Vol. LII, No. 3, p. 155 (March 1957).
4. "Forty Streets in One" Demonstration, *Electrical World*, 12/1/1923.

DISCUSSION

H. S. Nonneman:* I quite agree with the writers that the more of these facilities that are established, the sooner we will overcome many obstacles that now confront us, and the lighting of our streets and highways will be accelerated so that they will be made safer for the people of our country. It was my pleasure to be present at the dedication of the installation at Hendersonville, and I believe that it represents a lot of thoughtful planning in producing the laboratory that is now in operation there.

I am particularly interested in the continuous line lighting, covered in Item III of this paper, as we now have in the City of Dayton such an experimental installation, modified somewhat, to be sure, with one continuous row of lighting in the center of the street. Just recently I received the preliminary results of computations made here, using a discomfort glare evaluator, and we do find a system ratio to BCD of 1.06. This means that for the average observer such lighting appeared just slightly more uncomfortable than the borderline between comfort and discomfort. This, to my mind, bears out the improvement of such a system of lighting, and I know that more studies of like nature will be carried out at Hendersonville.

I know that the subject of the color of roadways and the type of pavement is one that is somewhat touchy, yet I think a great deal of study should be made of the effect of various types of lighting on different roadway surfaces. In fact, there are so many answers that can be obtained from the installation that has been described that work could be carried out almost continually on this type of installation.

Quite a number of years ago the General Electric Co. had such an installation in Cleveland, and it was my privilege to carry out tests on that installation every night from dusk to dawn almost continuously throughout one summer. The work done on that installation did much to further good street lighting, and with the years of progress now built into the new test laboratory at Hendersonville, great strides can be made at the present time to help all of us in our battle to prevent accidents and loss of life on our streets and highways.

R. R. Wylie:* The authors have raised some questions in my mind relative to the flexibility claimed for this laboratory. Only having studied the paper, it appears we have a rather inflexible system presented to us for building the future. Granted, these layouts provide I.E.S. Recommended Practice illumination levels as of today. They also permit restricted laboratory evaluations. But, do they provide economic, realistic possibilities for creative research at whatever levels we may have in the future? The daylight photographs show fixed standards of spacing of luminaires. They show but little flexibility in exceeding the higher mounting heights we are recommending today. Is it not entirely credible to hope and to believe in 300-500 foot spacings, with 40- to 50-foot mounting heights in the future? It almost seems an economic necessity.

I believe our European friends reporting in the International Lighting Review, No. 1, 1958, have hit upon the idea of a non-obsolescent laboratory. J. F. T. Von Heemskerck Veeckens, in "Outdoor Laboratory for Street Lighting" details an admittedly initially expensive laboratory, but one which looks to the future. In the European laboratory, portable masts are mounted on movable trucks. These can be placed at any site. They can be spaced along the roadway on any spacing and are not fixed as to roadway width. What is equally impressive, the luminaires can be mounted at any height up to above 40 feet. I believe this is true flexibility and building for the future.

Returning to the installation reported in this paper, how can a realistic evaluation, which is honestly salable to a client, be made of the effectiveness claimed, say for lighting of a downtown business area? There are no buildings to

*Dayton Power & Light Co., Dayton, Ohio.

*Sylvania Lighting Products, Commercial Engineering Dept., Salem, Mass.

reflect light and produce the cheerful, prosperous effects alleged. How can dynamic seeing researches be conducted at today's and tomorrow's speeds in this limited space? I believe the authors will grant their importance.

The authors stressed the growing "interest in appraising over-all visibility, and seeing both under illuminants giving true color appearance of objects and people, and under those causing distortion of true color appearance." Reference was made to "visitor's opinion polls indicated in excess of 60 per cent favoring true color producing illuminants." Substance can be given to these statements only if a full detailing can be provided on the comparative polling techniques. From here, it appears that the old story "of seeing better under yellow lights than under white lights" is being revived. Only this time, in reverse.

PAUL BOX:* The principle behind the "Crossroads of Light" is basically very sound, and in this I am sure most of us are in agreement. Unfortunately, from the standpoint of full and representative visual appraisal of differing systems, I feel the facility possesses several limitations. No doubt most, if not all, of these limitations were recognized in the planning stage, and the actual installation represents an economic compromise between the minimum layout for outdoor photometric research, and the more extensive spread necessary for effective and realistic visual observation. My comments, therefore, are directed toward acknowledgement of the observation limitations, exclusively.

One exception to this approach I shall have to make initially, and that concerns the apparent error in the tables, where the fluorescent luminaires are all described as Type I, instead of V or wide IV.

The lengths of test sections appear to be generally adequate, except for the introduction of different pavement types, and except for the residential section. With reference to pavements, we should all be in agreement that such a comparison is an important element in determination of relative visibility. However, when viewing a system where pavement types are segregated at the roadway center line, I do not believe the effect is at all representative, since light reflections viewed by the approaching drivers' eyes are based on two differing surfaces, when the total roadway surface in view is considered. It would seem a better approach to retain sections of the lengths now installed, only surfaced entirely by one material, and to add an equal length of the other surface type. This approach was utilized for obvious reasons on the narrow residential section.

In connection with the residential length, I should like to see 300-foot, instead of 200-foot sections of each paving material installed, so that mounting height ratios of 10 and even 12 could be demonstrated. In Kansas City, Mo., for example, between five and ten thousand installations were made on such ratios, utilizing enclosed Type I distribution. Certainly where block lengths resulted in ratios of about 10, the lighting produced has generally been conceded as satisfactory. There were some 12 to 1 ratios under favorable foliage conditions which also represented effective treatment.

With regard to luminaire distribution types, lamp sizes and street width selections, I think a generally excellent representation is available. I have already commented on the residential spacing; however, on the artery section it seems the spacing is also rather limited. The initial footcandle values tabulated appear to be considerably in excess of average country-wide arterial requirements. I believe the installation would have been more representative if spacings such as 125 feet were also available.

On the retail business section, I wonder if 70 feet of street width is typical. Would not 60 feet have been more nearly average for both the arterial and the whiteway? A second factor in connection with both of these sections concerns the background. Without considering store lighting and building reflectances which are such an integral part of business frontage, I fail to see how such lighting can be really visualized.

The experimental sections are certainly commendable, and if they are not intended for visual observations by the layman with an eye for ordering same, they should be entirely adequate. I believe most of us will be quite interested in the results of current and future studies of these systems.

R. M. SWETLAND AND K. D. TOBIN:* We appreciate the discussers' interest and their constructive comments relative to this facility. We compliment Mr. Nonneman upon his many contributions to roadway lighting progress through the years and, especially, for his recent pioneering in continuous-line lighting for traffic streets.

Mr. Wylie's suggestions for greater flexibility in luminaire spacing and mounting heights are heartily approved, and were considered in the initial planning of this project. However, both ground area, and budget limitations precluded their implementation. The "color opinion" poll was conducted only on the retail business section, under 1.5 to 3.0 footcandle levels. The only question asked was, "Which illuminant do you prefer from the over-all visibility and comfort standpoint?"

The suggestion, by both Mr. Wylie and Mr. Box of a more realistic building facade backdrop along the retail business sections was considered, also, in the initial planning of this facility. Although this has not been accomplished as yet, it is still in the long range plan.

Mr. Box comments on the different pavement surface arrangements—center-of-roadway division was judged effective where a symmetric staggered or opposite luminaire positioning prevails. For the one-side spacing along the residential section, however, it is agreed that each pavement type should be full roadway width.

It appears to be the consensus of our IES Roadway Lighting Committee, that a "broad Type I" light output designation is advisable for fluorescent luminaires having a symmetrical output on either side of the linear axis.

*Traffic Dept., Kansas City, Mo.

*Authors.

Most talked-about subject in the industry ... a complete report on the studies by Dr. H. R. Blackwell at the University of Michigan will be a feature of the June issue of ILLUMINATING ENGINEERING. Also in this special issue will be numerous applications of installations meeting the new IES recommended levels, based on the data obtained from the Blackwell studies.

INSTALLATION AT NUNN-BUSH SHOE STORE, 102 NORTH MAIN ST., DAYTON, OHIO.

Lighting a Shoe Store

LIGHTING OBJECTIVE: To provide a high level of general and display lighting for merchandising and to develop an atmosphere inviting to passers-by.

GENERAL INFORMATION: This "L"-shaped, two-entrance store which was recently redecorated and relighted is shown in plan in Fig. 2 and in section in Fig. 3. Colors and reflectances are as follows:

ceiling (plenum)	white	85% RF	display cases	natural walnut	30% RF
walls	natural walnut	30% RF	chairs		
floor	brown, black,		seats	light brown	50% RF
	white (speckled)	20% RF	arms	natural walnut	40% RF

INSTALLATION: The old ceiling height of 11 feet 10 inches was lowered to 9 feet 4 inches by installing two-foot square Honeylite aluminum panels (Hexcel Products, Inc.) on metal "T" framing (Eastern Products Corp.), suspended 2 feet 6 inches below the old ceiling. Sixty-four 72-inch T-12 and sixteen 48-inch T-12 deluxe warm white fluorescent lamps, installed in Kayline strip

(over)

A.I.A. File No. 31

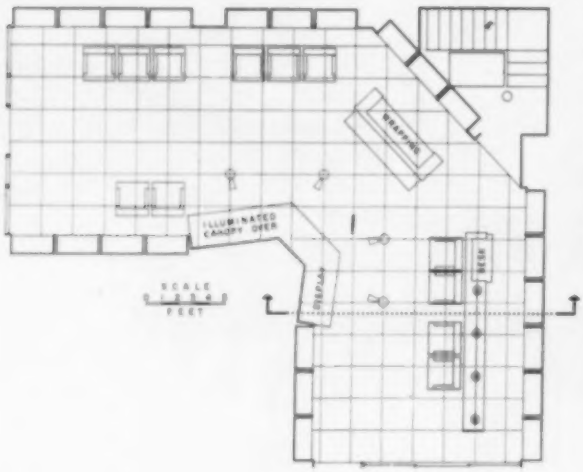
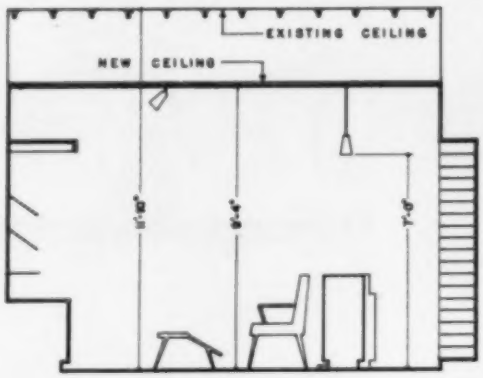


Figure 2. (left). Plan view of store.

Figure 3. (below). Cross section.



units mounted on the old ceiling in rows 15 inches on centers, provide an average level of 120 footcandles at shoe-bench height.

Additional accent lighting is provided on the counter and display areas. There are four 100-watt Prescolite catalog No. A-54 incandescent units suspended 4 feet above the counter by a custom-designed hanging system of stain-finish aluminum tubing. The average illumination level on the counter is 140 footcandles. The wall display is illuminated by four 100-watt Prescolite incandescent units aimed at the display and by eighteen 20-watt T-12 deluxe warm white fluorescent lamps mounted in the canopy over the display rack. The canopy is open at the top and equipped with Honeylite panels on the bottom. Illumination on the display rack under the canopy is 150 footcandles.

Brightnesses of the major room surfaces are:

ceiling panels at 45°	150 fL	chair seats	46 fL
walls	25 fL	floor	18 fL

Lighting designed by Hart and Hart, Architects, and installed by G. E. L. Electrical Contractors, both of Dayton, Ohio.

Lighting data submitted by D. C. Fiebiger, Lighting Representative, Dayton Power and Light Co., Dayton, Ohio.

Published by the Committee on Publications of the Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

Figure 1. High-level arena and permanent seating lighting.

High Levels in a Multi-Use Arena

BUDGET and adaptability were the deciding factors influencing the selection of incandescent sources for lighting the main arena of the Health and Physical Education Center, Montana State College in Bozeman. The area, which seats 12,000 is used for sporting events, rodeos, musical productions, theatre-in-the-round and ice shows. Illumination level required in the 70,000-square-foot area is 100 footcandles, capable of being blacked out rapidly for theatrical performances.

The comparatively short life of incandescent lamps at first appeared to be a stumbling block, access for re-lamping in the 90-foot high ceiling being the problem. However, it developed that a catwalk would be needed for servicing the heating and ventilating units and that an extension of this catwalk could provide access for maintenance of the lighting system.

Fig. 1 shows the portable basketball floor in place, portable bleachers at right and the folding bleachers directly ahead. Above the folding bleach-

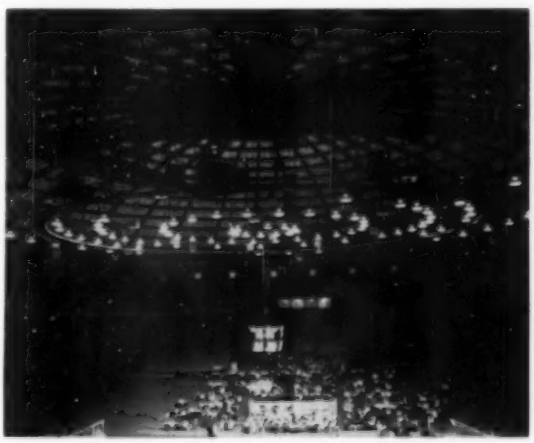


Figure 2. "Tournament play" lighting.

Alex G. Drapes, *of Drapes Engineering, Great Falls, Mont., won first prize with this installation in the 1958 Pacific Northwest Regional contest for MMILJ, having previously been first in the Inland Empire Chapter's contest.*

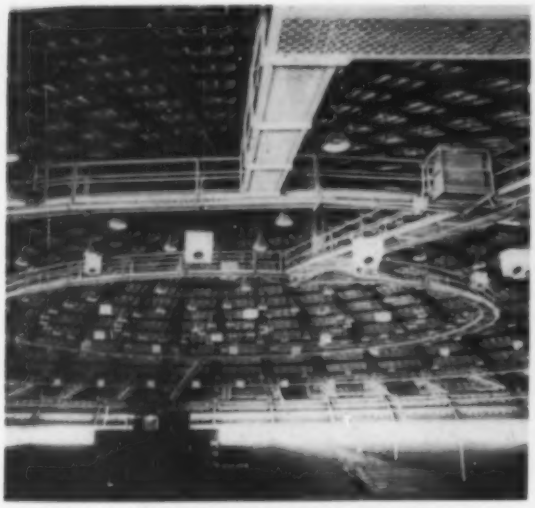


Figure 3. Catwalks from which lighting is serviced.

Figure 5. Illuminated scoreboard.

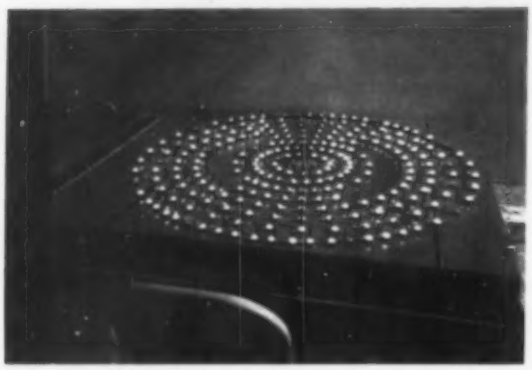


Figure 4. Lighting console in control booth.

ers is the permanent seating, which extends on up to the radio control booths at the top.

The 238 high-bay incandescent units, with spun aluminum housings, are arranged in a concentric circle pattern. Fixtures over the arena have 1500-watt lamps and those over the permanent seating use 1000-watt lamps. Average level in the arena is 120 footcandles with less than five per cent variation from corners to the center. During basketball games, only the lighting over the portable floor is used, although for pre-game and half-time activities the lighting can be varied as needed to meet the individual occasion.

The two center rings of lights are used for such activities as wrestling or boxing, where the focal point is at the center of the arena. These center rings are on hangers and are mounted at a height of 60 feet from the floor, providing up to 170 footcandles at the direct center of the arena.

The other fixtures are individually hung from the ceiling on swivel hangers, those fixtures over the main arena having wire guards for protection against baseballs and golf balls. These guards have proved reasonably successful.

The lighting servicing is done from the catwalk, except for the two center rings which are lowered to the floor. All other units in the dome can be swung to the circular catwalks, which are joined with transfer units running from the tops of the control booths on each side. Power outlets, follower spots and special lighting equipment are located on the catwalks.

Each lamp in the dome is individually controlled by a low-voltage relay and can be turned on or off to meet varying requirements. The control panel is simple enough for a novice to operate. It is located in the lighting and sound control booth. The main console is laid out as a miniature ceiling lighting plan on the control board, with a pilot light representing each of the ceiling lights. Adjacent to each pilot light is an operating switch to turn that light on or off. On the left-hand side are the master control switches which control pre-set areas, such as for basketball practice, basketball tournament, low-level or high-level arena.

The scoreboard posed an interesting problem from the standpoint of reflections. After several experiments, a board was specified with individual illuminated signs, the numerals having each lamp recessed in a tube or grid shield.

For evacuation of the building in case of power failure, a 25-kw emergency generator set is located in the main service room. This is fired with natural gas and is fully automatic in operation.

Architect for this installation was Ozwald Berg, Jr. & Associates, Bozeman, Mont.; electrical contractor, Yellowstone Electric Co., Billings, Mont.

Theoretical and Practical Light Distributions For Roadway Lighting

By A. W. FOWLE
R. L. KAERCHER

THERE HAS BEEN a long felt need for a discussion and analysis of the development of present-day theoretical and practical light distributions for roadway lighting. Much work has been done in evaluating the lighting results obtained from given light distributions. However, little has been written about the problems of working backwards from a pre-established lighting condition on the roadway to the luminaire candlepower distribution required to produce that condition. This paper has been prepared to set forth the premise for such a theoretical light distribution, to explain the procedure for developing it and to discuss the results.

The basic roadway lighting problem to be resolved by illuminating engineers can be stated quite simply as one of creating adequate visibility distance of obstacles, objects or conditions on the roadway for night safety. Desirable but less important aspects such as comfort, appearance, color, etc., are omitted because they have little or no bearing on the intent of this paper. The most effective and economical solution to this problem is not simple, since the characteristics of the human eye are rather complex, to say the least.

There has never been full agreement among street lighting engineers as to the best and most practical means for prescribing or specifying roadway lighting to achieve desired results. Different countries have different criteria. Some use "lumens per linear foot of roadway," some use "horizontal footcandles" and others strive to deal in "footlamberts brightness." The American standard practice of using horizontal footcandles has been criticized and some feel it should be abandoned. One problem that arises immediately, in this paper, is that of ascertaining the most practical criterion to use.

It would appear that the most desirable approach would be to somehow use "visibility" as a criterion from which the light distribution could be directly computed. However, since the overall visibility aspects as related to street lighting cannot be precisely defined or measured some other aspect must be used which can be calculated or measured. The concept of "visibility distance" is suggested as it meets these requirements and is the basic end result to be sought in a roadway lighting installation.

Visibility distance is defined here as meaning the distance at which a given object of given size and contrast can be detected in order to take proper action to deal with it. Although considered as the end result to be achieved when analyzing light distributions, it is not the intent of this paper to discuss the problems of determining specific visibility distances. This requires taking into account factors for safety, speed, impaired vision, age of eyes, fatigue, abnormal distractions, etc.

In considering the various elements in street lighting that affect visibility distance, it has been found helpful to use Fig. 1 as a guide — with thanks to J. M. Waldram,[1] from whose paper the idea was obtained for this modified and Americanized version. This chart emphasizes, in the circles, the three major components of visibility distance generally believed to apply in American practice. Visibility distance depends on the capacity of the lighting system to reveal information to the observer. The eye will see contrasts — contrasts of objects against their background and contrasts upon the objects themselves. For a given contrast

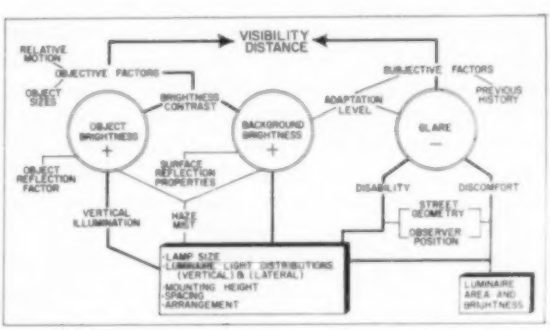


Figure 1. Relationship of controllable factors of lighting system and luminaire design with elements of visibilty distance.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, August 17-22, 1958, Toronto, Ont.
AUTHORS: Holophane Co., Inc., Newark, Ohio.
This paper accepted by the Papers Committee of I.E.S. as a Transaction of the Illuminating Engineering Society.

condition as the "rheostat on the lighting system is turned up" the visibility distance is also increased. There is also the reduction of visibility distance due to the negative factor of veiling glare which the lighting system produces.

Object and background brightness are, of course, the product of the incident illumination and the reflection properties of the object and background. While reflection factors can be determined for objects, pavements, etc., the actual factor for any surface varies and, therefore, its apparent brightness changes in relation to the change of *viewing angle* since all practical surfaces have both specular and diffuse components. It is impossible for the lighting engineer to control the reflection factors of surfaces or viewing conditions so that "brightness" becomes a somewhat impractical criterion.

The only fundamental visual element that can be considered reliable for any given lighting system is the illumination *on* the objects and backgrounds. There must be illumination before there can be any brightness. Given illumination values will always remain constant no matter what changes might occur in viewing position, reflection factors, wetness of surfaces, etc. However, what illumination values should be considered — vertical, horizontal, or what?

The illumination level and the reflected brightness from any surface intercepting the projected light flux will increase or decrease directly proportional to the increase or decrease of candlepower in that direction. The actual values will always be fixed for any given lighting system, type of luminaire and light distribution. The illumination level on, or reflected brightness from, any surface intercepting a ray of light will change as the angular relationship of the light ray and surface change with respect to each other. The illumination change is a function of the trigonometric relationship of the angles involved. The brightness changes are much more complex because of the complex nature of the reflection characteristics of the surfaces.

Only when a fixed surface is involved will the illumination values remain stable. The one surface that remains fixed for any condition is the *horizontal* roadway surface. Likewise, there is only *one horizontal footcandle* value on the roadway and it is by far the easiest to calculate and understand when dealing with the *horizontal geometry of a road* surface.

This can be analyzed another way. The system design and luminaire design factors in the two rectangular boxes at the bottom of Fig. 1 are the only factors which can be controlled by illuminating engineers. Mounting height, spacing, arrangement and lamp size are controlled by the application engineer, and light distribution and luminaire brightness are controlled by the design engineer. All other elements, no matter how important to overall visibility distance, are definitely uncontrollable, in the sense that the engineer cannot change or alter them as he can the lighting system.

The only practical way that visibility distance can be affected, then, is by changes in the controllable factors. It would, therefore, seem reasonable that they can properly be considered as valid representations for visibility distance in specifying a lighting system because all functions of the lighting system depend on them.

For a fixed system design of mounting height, spacing, arrangement and overhang, a given candlepower distribution will produce definite vertical and horizontal footcandle values. These, in turn, will produce definite object and pavement brightness values for one static condition of viewing position and reflection factors. With the luminaire distribution remaining the same, a change in any one of the system design factors will change vertical footcandles and horizontal footcandles. This will effect visibility distance through changed brightness contrasts or levels of brightness. Likewise, with system design remaining the same, a change in candlepower distribution will affect contrasts and levels of brightness. However, if both system and candlepower distribution design remain constant, by simple mathematical relationship there can be only ONE possible horizontal footcandle value at any point on the roadway between adjacent luminaires. If there is a definite distribution of the point by point illumination over the roadway, there is immediately established the *average* horizontal illumination and the *uniformity* of illumination.

From this standpoint, it seems rational, therefore, that the most practical criterion to use in place of visibility distance is average horizontal footcandles *and its uniformity*.

Previous Studies

Previous studies of theoretical light distributions by Sweet[2] produced a vertical candlepower curve as shown in Fig. 2. This was developed from an established uniformity of illumination along a horizontal line on the roadway between two consecutive lighting units. The curve is based on 100 candlepower at nadir and a spacing ratio of 8 MH. Other similar curves were developed for other spacing ratios of 6, 10 and 12 MH.

Later, Sweet and Rolph[3] developed lateral distributions for side mounted luminaires by swinging the vertical distribution of Fig. 2 laterally about the axis of the luminaire to produce two small

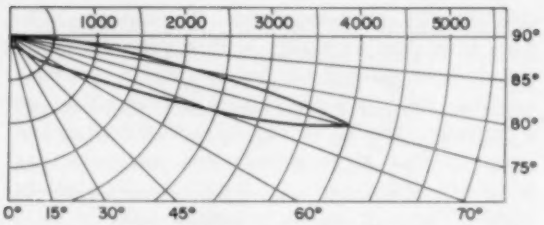


Figure 2. Vertical distribution developed by Sweet for spacing ratio of 8 MH.

sectors of a cone to cover the roadway. The trace of this on the horizontal road surface produced two sectors of a circle as shown by the dotted lines in Fig. 3. Modifications were introduced with respect to practical sharpness of cut-off and angular relationship for what was then felt to be required in the way of light beyond property lines. This resulted in the distribution shown by the solid line in Fig. 3.

These vertical and lateral distributions have been modified in recent years through much experience with practical development and use of many light distributions for different roadway width and spacing conditions. Present distributions are based on requirements for maximum utilization and uniformity of horizontal illumination and roadway brightness. It is now known, for example that it is not necessary to deliberately direct light behind the luminaire to any great extent for "house side" illumination as was believed necessary in earlier years. With present distributions there is generally an excess of "spill light" on the back side of the luminaire when candlepower in the maximum cone is reduced to half maximum value at the "reference plane."

The plane of maximum candlepower used in the study of Sweet would produce a "line of light" on the roadway running between consecutive luminaire positions. The cones of maximum candlepower used in the Sweet and Rolph study would produce segments of circles of light around the luminaire having a radius out from the luminaire equal to the tangent of the vertical angle of the cone. The lines and circles of light would have a level and uniformity of illumination that would depend upon the candlepower intensity of the light distribution. In both of the studies referred to, the required candlepower distribution was obtained from a pre-established illumination pattern.

If the concept of the transverse plane of McPhail,[4] or the longitudinal inclined plane of Rex[5] were used, straight lines of light across the roadway and down the roadway would result. Their locations would be determined by the intersections of the planes with the horizontal roadway surface. As above, distributions of candlepower in these planes can be calculated to produce a prescribed level and uniformity of horizontal footcandle illumination along the lines on the roadway surface.

If the correct horizontal footcandle distribution over the roadway can be established, the required candlepower values for lighting the entire road surface can be determined in a similar but more complex fashion. Rather than finding a vertical and lateral distribution curve to produce lines of light on the pavement, the problem becomes one of determining the solid pattern of candlepower distribution to properly light the entire roadway area to an average level and uniformity of horizontal ilumination. On paper, it becomes a matter of developing the "isocandle chart" from a horizontal footcandle chart.

Determining the Distribution — Typical Example

Known Factors: (Controllable Factors of System Design)

Mounting Height = 30 feet
Roadway Width = 30 feet (also 40 feet)
Spacing = 210 feet (or 7 MH)
Arrangement = Staggered

To Be Produced:

Mean Average Horizontal
Illumination = 1.0 Footcandle at 30 feet (or higher)
Uniformity of Horizontal
Illumination = 4:1 — Average: minimum footcandles (or better)

Unknown:

Candlepower Distribution

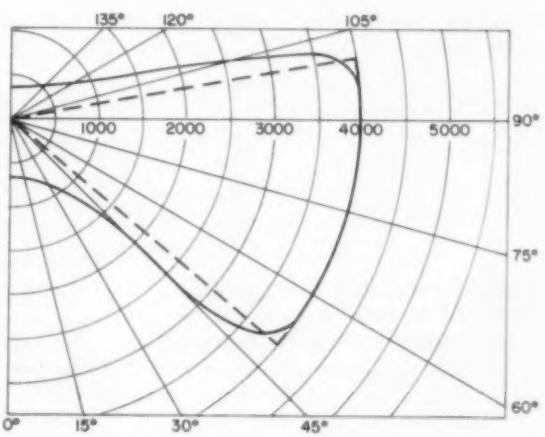


Figure 3. Lateral distributions developed by Sweet and Rolph from vertical distributions in Fig. 2.

System Design

This particular example is only one of many that could be selected. It is one that might apply to a two-lane highway or a traffic thoroughfare where maximum economy, by means of long spacings, would be desired. In establishing the foregoing dimensions, the most extreme conditions were used that might be encountered in practice for the service intended, such as a 210-foot spacing and a 40-foot wide roadway. At the same time, this particular study was also checked through for a 30-foot wide roadway, which would be more representative of a two-lane highway or half of a divided four-lane expressway.

Different system design conditions will always result in different light distribution requirements. However, if the extreme dimensions are used, anything more favorable dimensionally, will simply result in higher averages and better uniformity.

Illumination Level

The level selected for this example was one that might apply to a two-lane or 30-foot wide highway where at least 0.8 footcandles maintained average could be obtained with an 80 per cent luminaire maintenance factor. This is the current recommended[6] value for "Heavy to Heaviest" vehicular traffic with "Little or No" pedestrian traffic.

Uniformity

As pointed out earlier, since uniformity of illumination is one of the two important criteria for determining a candlepower distribution, a definite ratio of average to minimum footcandles needs to be established. For this case the 4 to 1 ratio recognized as acceptable in the *American Standard Practice for Street and Highway Lighting*[6] was used.

Sweet and Rolph both assumed a more severe uniformity condition of 4 to 1 maximum to minimum horizontal footcandles in their studies, but they specified no average value. The same could be done here, just as easily, if this were the established basic procedure for specifying roadway lighting. For any given pattern of illumination on a roadway, that is, for any light distribution and system design, there is only *one* maximum, *one* minimum, and *one* average horizontal illumination value. The average to minimum ratio is more realistic and it is more limiting because a specification of maximum and minimum *only* could be met with many different average levels.

Procedure

The first step is to consider that there is projected onto the rectangular section of roadway area the necessary total quantity of lumens to produce the average level specified.

From this, and the "average to minimum" ratio that has also been established for the area between two adjacent luminaires, the *minimum* horizontal footcandle value *from all contributing luminaires* is determined. The minimum value should be kept as high as is practical for best performance from an illumination standpoint. This requires higher candlepower at the higher vertical angles. It should not be to the extent that the veiling glare effects resulting from this candlepower would exceed tolerable limits. A background of much experience is the best guide in determining the proper balance between roadway illumination, uniformity and veiling glare. This is discussed further under "Other Considerations."

Of more importance is the fact that experience will show *where* the minimum point should be located. This location is a vital part of the overall evaluation of the horizontal illumination pattern. It is related to the next step which is to develop the optimum pattern of illumination over the entire horizontal roadway area from a system of luminaires. This is quite involved. It requires point by point checks and rechecks of the illumination pat-

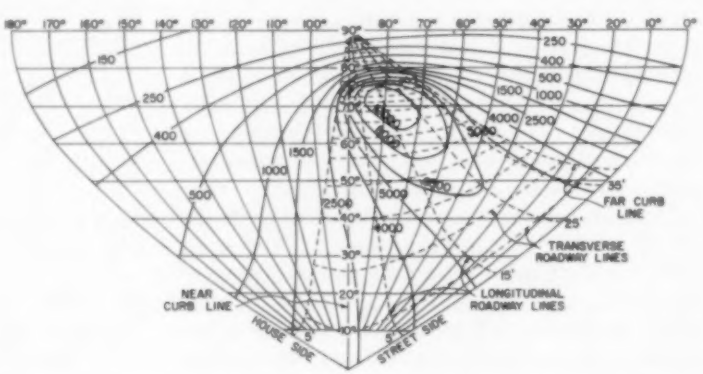


Figure 4. Spherical isocandle chart developed by outlined procedure for the example given in this paper.

tern and the proportion of flux from each contributing luminaire. Experience is also most helpful in facilitating this operation. This important step provides "point by point" values which are the basic framework for not only the horizontal illumination pattern but for computing the resulting candlepower distribution. Also, this provides a means of determining the total amount of light flux between curb lines. The design objective would be to direct the required amount of light flux into the roadway in the proper uniformity relationship.

The resulting footcandle values on the roadway can then be transferred to the surface of an imaginary sphere surrounding the luminaire, in terms of the candlepower values required to produce them. The "flattened sphere" or web used for easy plotting and reading that we are most familiar with in street lighting is shown in Fig. 4.

Further refinement can be produced by cut and try methods. This permits smoothing out and determining the actual distribution of light along and across the roadway from the system of luminaires. Totaling all of the footcandle values at the centers of, for example, 10-foot by 10-foot squares over the roadway area will provide a measure of average illumination. For example, if it were found by this method that the average value did not produce the desired uniformity ratio for the originally selected minimum value, the minimum value could be increased in order to provide the correct ratio. However, upon increasing the value of the minimum point (and this could not just be arbitrarily increased at any one point without following a reasonable gradient from low to high values at nearby points), the average illumination would also increase, since the total amount of light flux on the roadway would be greater. By increasing the average, the *ratio* of average to minimum would be destroyed and it would be necessary to raise the minimum value or bring the average value back down to the original level (which had been established in the first place as being perfectly satisfactory for the conditions involved). This could be done by reducing high values at some other location, thus approaching a more uniform distribution of light over the entire roadway.

The final established candlepower values resulting from this method are plotted as the isocandle chart shown in Fig. 4.

Other Considerations

Other factors influencing visibility distance which are affected by the controllable factors of system and luminaire design are:

(1) Roadway brightness.

(2) Disability veiling brightness (veiling glare).

These must be considered in the overall development of a luminaire distribution because they are directly related to one another.

For a given observer viewing position with respect to a section of roadway area, the pavement brightness will increase as the vertical angle of candlepower emission increases. (Solid curve in Fig. 5). For a given observer position, a light source will produce higher veiling glare as the vertical emission angle increases, as shown by the solid curve in Fig. 6.

This is further illustrated, in a different way, in Fig. 5 and Fig. 6 where the resultant horizontal illumination has been made to remain constant by adjusting the candlepower values as the vertical angle increases). The dotted curves again show an increase in pavement brightness and veiling glare per horizontal footcandle as the vertical emission angle increases.

These relationships have been calculated for three different systems of luminaires and plotted in Fig. 7. The luminaire systems are all designed to produce an equal horizontal illumination level of 0.2 footcandle. Three types of luminaires, having different candlepower distribution patterns, and different vertical angles of maximum candlepower, are used. The higher angle types produce higher pavement brightness and, also, higher veiling glare conditions for an equal illumination level.

Generally, in practice, the higher angle type distributions, which are needed to produce the required illumination uniformity at longer spacings, will produce higher pavement brightness. It would

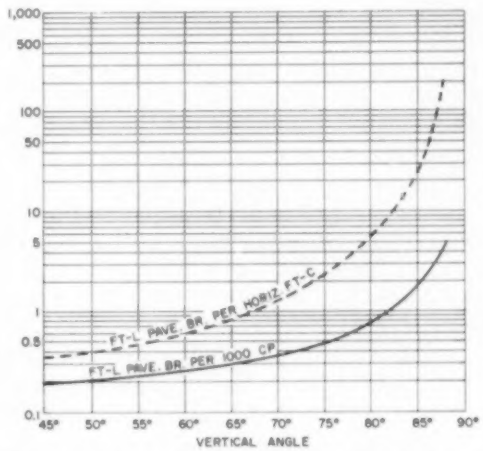


Figure 5. Solid Curve — Relationship of pavement brightness to vertical angle of candlepower emission of one light source. Candlepower remains constant. Dotted Curve — Relationship of pavement brightness to vertical emission angle for equal horizontal illumination from one luminaire. (Pavement surface was typical worn asphalt used by Reid and Chanon.[7])

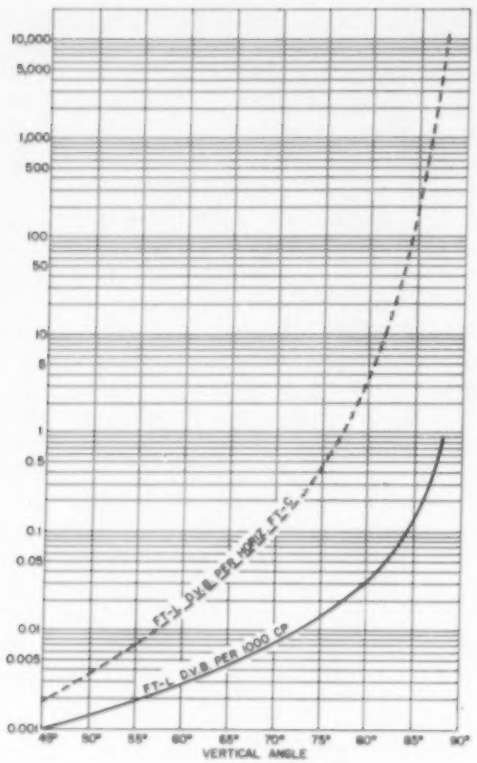


Figure 6. Solid Curve — Relationsihp of disability veiling glare to vertical angle of candlepower emission of one light source 100 feet from observer. Candlepower remains constant.

Dotted Curve — Relationship of disability veiling glare to vertical emission angle for equal horizontal illumination from one luminaire, 100 feet from observer.

be possible, theoretically, to have two different roadway lighting systems with different spacing ratios and equal conditions of illumination level and uniformity. This would require different candlepower distributions for each case, the greater of the two spacing ratios requiring higher candlepower at the higher angles to maintain uniformity. This, in turn, would produce higher pavement brightness levels and higher veiling glare, which would result in different visibility distances for equal horizontal illumination conditions. However, this could only be for two entirely different roadway lighting systems having different spacing ratios and using luminaires with different candlepower distributions.

These examples have been mentioned to show the rather complex relationship of pavement brightness, veiling glare and uniformity of illumination to candlepower distribution of the luminaires. It occurs because, to provide better illumination uniformity at a given spacing ratio, it is necessary to direct more flux between luminaires and this requires much higher candlepower at the higher vertical angles. A given candlepower distribution can produce only one average value and uniformity of horizontal illumination, pavement brightness and veiling glare, for a given system design and observer position. For any given system design and observer position, the pattern of horizontal illumination on the roadway is a definite measure of the amount and uniformity of pavement brightness and veiling glare because the illumination pattern determines the candlepower distribution.

These relationships must be kept in mind in the overall problem of developing a candlepower distribution and a proper balance arrived at by the designer. In practice, this means generally reducing candlepower values at angles above the maximum emission angle, as rapidly as possible, to keep veiling glare at a minimum because this is affected, more than pavement brightness, by candlepower at the extremely high vertical angles.

Discomfort glare is another negative factor that is the result of candlepower toward the eye of the observer. It is of secondary importance in the overall development of a candlepower distribution

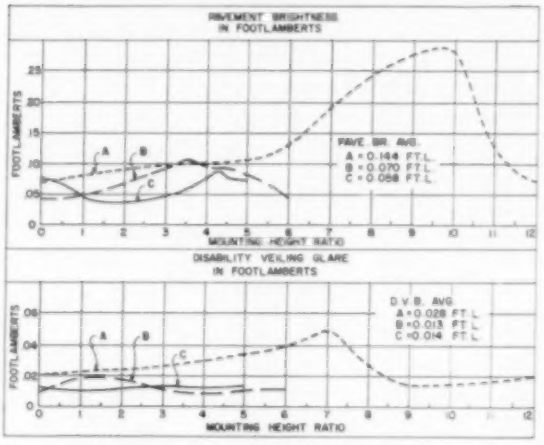


Figure 7. System pavement brightness and system veiling glare for three different luminaire systems and spacing ratios with lamp sizes to produce equal average horizontal illumination of 0.2 footcandle. This places all three luminaire systems on a common basis regardless of spacing ratio or vertical angle of maximum candlepower.

Luminaires used: A — Typical high angle IES Type I Luminaire with 6000-lumen lamp, spacing ratio of 12 MH. B — Typical Type II low angle luminaire with 2500-lumen lamp, spacing ratio of 6 MH. C — Typical Type V radial-wave reflector with 2500-lumen lamp, spacing ratio of 5 MH.

Further results from these systems are shown in Table II. (Calculation methods and factors for system roadway brightness and system veiling glare were based on methods used by Rex.[5])

where visibility distance is of primary concern, since discomfort glare has no effect on the ability to see or not to see.

Discomfort glare is more complex to evaluate since it depends on brightness of the surround as well as source brightness. For any given constant condition of surround brightness, discomfort glare will vary as a function of apparent source brightness. This, in turn, depends on the projected luminaire area and candlepower toward the observer. For a given luminaire area, the discomfort aspect will be determined by the *same* candlepower value that determines veiling glare. Fortunately, it follows that control of candlepower distribution from a veiling glare standpoint will also control discomfort glare in the right direction.

Results

The candlepower distribution theoretically developed by the previously described example produces the horizontal illumination results shown in Table I.

The resulting vertical distribution (Fig. 8), in the plane of maximum candlepower, shows the vertical angle of maximum candlepower to be at 72½ degrees. The resulting lateral distribution, Fig. 9, shows the lateral width of the beam at one-half maximum candlepower to be 25 degrees, which brings this distribution under the classification of IES Type II, as should be expected from past experience, for a roadway width of 40 feet.

The spherical isocandle chart (Fig. 4) illustrates that the majority of light flux is confined to the 40-foot wide road for which this distribution was developed. This is necessary for maximum utilization. The relationship can be seen by comparing the candlepower distribution with the near and far curb lines projected back on the spherical chart.

Fig. 10 shows the resulting pavement brightness along a line down the center of the roadway (same pavement surface[5,7] used in previous examples) and the veiling glare produced by this theoretical luminaire system. These curves are of the same type, and computed in the same way, as those in Fig. 7.

Several aspects of the theoretical distribution are compared with those of the three different luminaire distributions used for the data in Fig. 7. The results are compared in Table II. Some interesting comparisons can be made of the effects of different distributions on the factors of visibility distance.

(1) Average system pavement brightness per horizontal footcandle from the theoretical distribution is comparable with that of other distributions of similar vertical angle of maximum candlepower.

(2) The pavement brightness generally follows

TABLE I.

Width of Roadway	Average Horizontal Footcandles		Ratio of Average to Minimum Horizontal Footcandles
	Mean	Maintained*	
30 Feet	1.04	0.83	3.6/1
40 Feet	0.93	0.74	3.9/1

*80 per cent Luminaire Maintenance Factor.

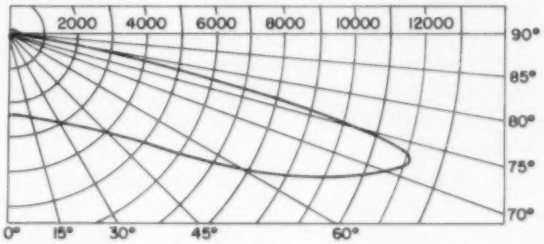


Figure 8. Vertical distribution in plane of maximum candlepower of theoretically developed distribution.

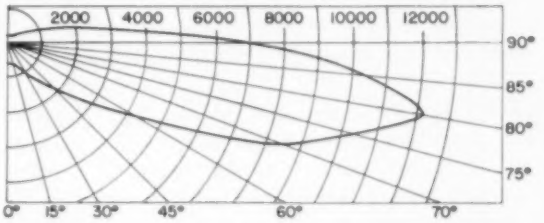


Figure 9. Lateral distribution in cone of maximum candlepower of theoretically developed distribution. See, also, Fig. 4.

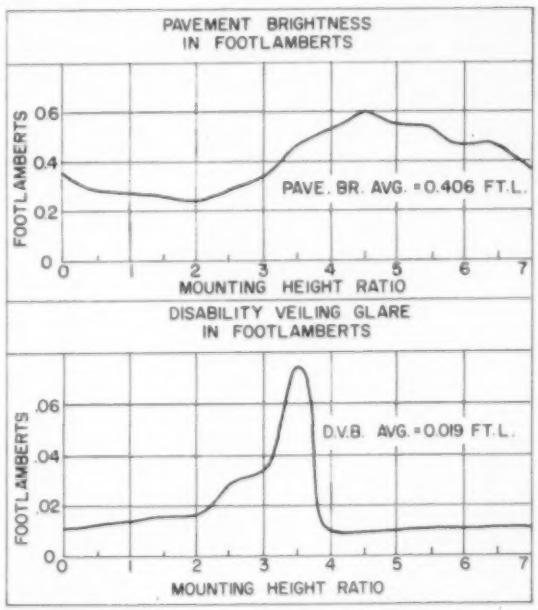


Figure 10. System pavement brightness and system veiling glare resulting from the theoretically developed candlepower distribution.

the axiom previously presented that the brightness results depend upon the vertical emission angle or that the "higher angle footcandles" are worth more in pavement brightness than "low angle footcandles."

(3) The theoretical distribution results in low system veiling glare, and on a "per footcandle" basis is considerably lower than the other distributions shown. This is the result of deliberately reducing the amount of candlepower emission at the higher "glare angles" in order to reduce the disability effect. While these figures are not all inclusive, since they represent a limited evaluation of the system, the reduction in veiling glare has been accomplished with little or no sacrifice in pavement brightness level and uniformity and horizontal illumination uniformity.

(4) As the vertical angle of maximum candlepower must be raised to maintain reasonable uniformity of illumination at longer spacings (Luminaire A), the resulting increase in pavement brightness is obtained only at some sacrifice of system veiling glare. Fortunately, the increase in per cent loss due to D.V.B. is somewhat less than the increase in pavement brightness. Therefore, the overall net improvement in visibility distance is increased when using the longer spacing ratio, higher vertical angle distributions.

(5) These limited comparisons indicate that further evaluations can and should be made of the effects of different light distributions, and the refinements thereof, on the factors of visibility distance. It would appear, from calculations already made (Table II) and from practical observations, that where around a 5 to 1 uniformity of illumination is adhered to adequate pavement brightness will be assured. This would seem to be true regardless of spacing ratios or candlepower distributions because in order to obtain the uniformity of illumination it is necessary to have the proper candlepower distribution for the spacing ratio involved.

Conclusions

There are several factors involved in the overall aspect of visibility distance in a roadway lighting system. Two in particular stand out, the level and uniformity of horizontal illumination. Both are dependent on system design factors — spacing, mounting height, street width, luminaire overhang and arrangement — and the luminaire design factor of candlepower distribution. These factors are all interrelated mathematically and interdependent upon one another. Changing one affects all others.

For a given candlepower distribution and system design definite illumination results will automatically be obtained and can be computed. It is also possible to go in the other direction, from a given illumination level and uniformity for a fixed system design, to the candlepower distribution required to produce it. This can also be computed.

There are negative factors of veiling and discomfort glare that are also affected by candlepower distribution. Their effect can be minimized by proper control of the candlepower at the upper "glare angles." Candlepower at these angles also affects pavement brightness, hence, overall visibility distance, but this can still be related to illumination uniformity for a given system design. In the final analysis, proper balance of light distribution is required for the roadway lighting application intended. Low angle distributions should be used for the shorter spacing ratios to obtain "low-glare" high-footcandle roadway lighting. High angle distributions should be used for the low illumination level, long spacing ratio, installations where pavement brightness is especially important in silhouette type of discernment.

TABLE II — Results of Three Typical Luminaire Systems Used for Fig. 7 and Theoretical Distribution of This Paper, Fig. 10.

Luminaire†	Vertical Angle of Maximum Candlepower	Maximum Candlepower	Spacing Ratio	Average Horizontal Footcandles	Average Pavement Brightness in Footlamberts	Footlamberts Pavement Brightness per Horizontal Footcandles	System Veiling Glare (D.V.B.) in Footlamberts	Per Cent Loss* Due to D.V.B.	Footlamberts Veiling Glare per Horizontal Footcandles	Horizontal Footcandle Uniformity		Pavement Brightness Uniformity	
										Average Footcandle	Minimum Footcandle	Average Footlamberts	Minimum Footlamberts
A	78°	3300	12 mh	0.2	0.144	0.72	0.028	20.5	0.140	5.0/1		2.5/1	
B	72°	1300	6 mh	0.2	0.070	0.35	0.013	14.1	0.065	5.0/1		2.1/1	
C	0°	425	5 mh	0.2	0.058	0.29	0.014	14.7	0.070	3.3/1		1.7/1	
X	72½°	12000	7 mh	1.04	0.406	0.39	0.019	18.5	0.018	3.6/1		1.7/1	

†Luminaire: A = High-angle Type I, 6000-Lumen; B = Low-angle Type II, 2500-Lumen; C = Radial Wave, 2500-Lumen; X = Theoretical Candlepower Distribution.

*Note: The per cent loss in D.V.B. is obtained from data by Reid and Chanon.[7] It represents the effective loss in visibility distance due to different levels of system veiling glare.

Understanding these relationships is most helpful in developing accurate and desirable luminaire distributions to satisfy the requirements of the application engineer for most effective roadway lighting. The application engineer can utilize light distributions most effectively by always recognizing the maximum spacing to mounting height ratios for which they are designed, in order to maintain proper illumination uniformity.

References

1. Waldram, J. M.: "The Revealing Power of Street Lighting Installations," *Transactions Illuminating Engineering (London)*, 3, 173 (1938).
2. Sweet, Arthur J.: "An Analysis of Illuminating Requirements in Street Lighting," *The Journal of the Franklin Institute*, May, 1910.
3. Sweet, Arthur J., and Rolph, Thomas W.: "Asymmetric Light Distribution Requirements for Side-Mounted Street Lighting Units," *Transactions of the Illuminating Engineering Society*, October, 1927.
4. McPhail, Robert G.: "Analysis of Light Distributoins from Linear Source Street Luminaires," ILLUMINATING ENGINEERING, Vol. LIII, No. 4, p. 193 (April 1958).
5. Rex, Charles H.: "Luminaire Light Distribution Principles," ILLUMINATING ENGINEERING, Vol. L, No. 12, p. 587 (December 1955).
6. *American Standard Practice for Street and Highway Lighting*, Feb. 27, 1953, American Standards Association, published by Illuminating Engineering Society.
7. Reid, Kirk M., and Chanon, H. J.: "Evaluation of Street Lighting," *Transactions of the Illuminating Engineering Society*, Vol. XXXIV, No. 10 (December 1939).

DISCUSSION

CHARLES H. REX:* Studies such as this paper presents are one good way of making progress in roadway lighting. Serious investigation of the objectives of roadway lighting brings realization of the fact that visibility and its factors, such as pavement brightness, obstacle brightness and disability veiling brightness are the proper criteria, when accompanied by relative visual comfort ratings. The authors wisely used computations based upon visibility factor data in developing and comparing light distributions.

Extension of these studies to include some of the fundamentals of motor vehicle transportation will improve their opinion regarding the importance of visual comfort. Motorist enthusiasm and demand will rapidly extend and expand the use of roadway lighting. If the roadway lighting is pleasant and makes nighttime driving attractive, it will be installed. When installed, the lighting produces the many benefits of visibility. Increased use of roadway lighting and the visibility it produces is essential for the public welfare.

Instead of considering one goal primary and the other secondary, let us produce roadway lighting which provides the over-all objective of both good visibility and good visual comfort. As the authors state: "Fortunately, it follows that control of candlepower distribution from a veiling glare standpoint will also control discomfort glare in the right direction."

The suggestion that "visibility distance" be substituted for visibility is based upon progressive motives. However, progress will be accelerated if the authors define what they have in mind. The clarification involved in doing so may bring them around to the visibility criteria under roadway lighting conditions.

We all know that visibility distance has been used to describe the effectiveness of automobile headlighting. This is often expressed in terms of the distance at which a representative low reflectance target is discerned under certain conditions of driver awareness. With good roadway lighting, the visibility distance of such an object may be largely a function of its size. For example, an object the size of an automobile may be readily visible under roadway lighting for several thousand feet ahead of the automobile driver.

With roadway lighting, we are interested in providing quick and certain discernment, detection and discrimination of objects which are large enough to be visible at specified distances. The brightness contrasts may be related to, but should be appreciably above, the threshold of bare discernment. Visibility distance must involve bare discernment due either to size, brightness contrast or driver vision and perception conditions. Visibility increase over bare discernment brightness contrast under roadway lighting conditions has been defined by Reid and Chanon[7] or visibility may be relative to the minimum brightness contrast *required* for the driver's visual task, as will be established by Dr. Blackwell. We believe that the authors will agree that if "visibility distance" is to be used as a criterion for roadway lighting, it should be explained and defined. Won't this involve brightness contrasts?

This paper makes liberal use of brightness data as criteria. The authors should supply diagrams and explain to the readers how the brightness data in Figs. 5 and 6 have been derived. By a fortunate coincidence, the data which have been supplied to them, and others, over a period of several years, have been presented in my recent paper,[5] Figs. 4, 5 and 8. The reader should be informed as to which data should be used. What is the practical significance of elevating an observer so that he can view a luminaire at the vertical angle of 85 degrees at a distance of 100 feet?

Under typical viewing conditions, doesn't the pavement brightness in footlamberts per 1000 candlepower *decrease rather than increase* with vertical angle and distance from the luminaire? If the data in the authors' Fig. 5 are used, why would a candlepower distribution such as that shown in Fig. 8 be desirable?

"Higher angle horizontal footcandles are worth more in pavement brightness than low angle footcandles." However, to obtain a horizontal footcandle on the pavement at a distance from the luminaire corresponding to a high angle requires very high candlepower.

It would be helpful to the readers, if the authors would supplement their illustrations based upon vertical angle scales with an additional scale in multiples of MH. Such a correlation for pavement stations and observer positions along the 0.5 MH, 1.5 MH and 2.5 MH roadway lines is available in "Luminaire Light Distribution Principles."[5]

Which longitudinal roadway lines and what observer paths were used in computing the data presented? The candlepower distribution developed provides maximum candlepower at the vertical angle of 72½ degrees, and the lateral angle of 80 degrees. We know, of course, that this maximum will impinge upon the pavement near the pavement station at a longitudinal distance of 3 MH along the 0.5 MH roadway line.

This paper shows that the conversion from horizontal footcandles for a roadway lighting system to brightness contrasts, then on to visibility (or even visibility distance), and then deriving the required luminaire candlepower distribution is a devious problem. For example, converting from horizontal footcandles on the pavement to disability veiling brightness along the driver's eye-level path involves

*Outdoor Lighting Dept., General Electric Co., Hendersonville, N. C.

complications which are avoided if the readily available luminaire candlepower along the longitudinal eye-level lines is used.

The splendid work which the authors have done will be more fully appreciated if it is thoroughly explained. We have suggested that this be done, even if an appendix is required to do so.

This paper proves that visibility factor data and criteria are essential in order to appraise the effectiveness of roadway lighting. It presents additional groundwork for future progress. The authors are congratulated!

References

1. Reid, K. M., and Chanon, H. J.: "Evaluation of Street Lighting." *Transactions of the Illuminating Engineering Society*, Vol. XXXIV, No. 10, p. 1209 (December 1939).
2. Rex, Charles H.: "Computation of Relative Comfort and Relative Visibility Factor Ratings for Roadway Lighting." ILLUMINATING ENGINEERING, Vol. LIV, No. 5, p. 291 (May 1959).
3. Rex, Charles H.: "Luminaire Light Distribution Principles," ILLUMINATING ENGINEERING, Vol. L, No. 12, p. 587 (December 1955).

H. F. WALL:* There are two pages of discussion in this excellent paper, ending with the statement "The most practical criterion of street lighting is average footcandles and its uniformity," which apparently serves as a justification for the methods used by the authors to determine an ideal candlepower distribution. I cannot agree with this statement, and I doubt that many others will agree that visibility or the effectiveness of street lighting is entirely dependent upon this factor. However, this is what the Standard Practice calls for, and I have often wondered what the resultant light distribution from a luminaire would be if based upon these requirements. The authors have done this most satisfactorily.

Fig. A shows our "ideal curve" which I calculated years ago, and which is still used in some of our specifications for street lighting luminaires. I was very pleased to find a similarity between mine and the authors' curve, particularly in the vertical distribution where maximum of one-half bare lamp candlepower is required at 85 degrees, twice bare lamp candlepower at 80 degrees, and where the maximum beam is at 72½ degrees. I found, at reasonable viewing distance, that a worn asphalt pavement becomes highly specular when illuminated by the 72½ degree beams and that candlepower above this angle could be reduced rapidly without decreasing pavement brightness appreciably. The authors' calculations resulting in a 72½-degree main beam would therefore be of great interest to me, particularly as to why they arrived at the angle of maximum beam candlepower. This paper contains practically no calculations for comments and comparisons by other designers.

*Public Lighting Commission, Detroit, Mich.

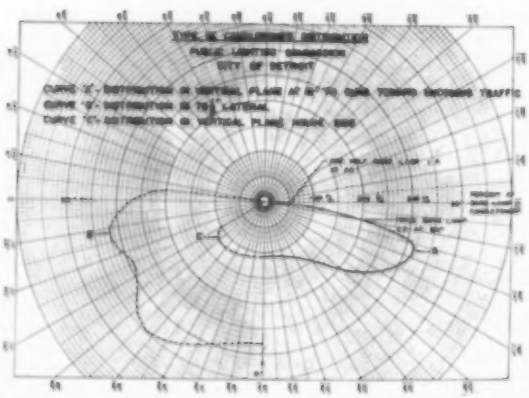


Figure A. Ideal candlepower distribution curve calculated by Wall for Detroit Public Lighting Commission.

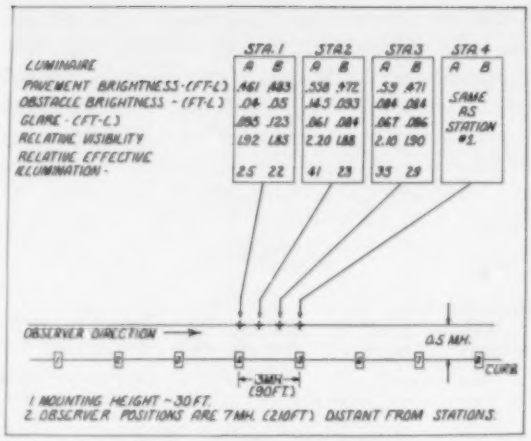

STA. 1
STA. 2
STA. 3
STA. 4
A B
LUMINAIRE
PAVEMENT BRIGHTNESS - (FT-L) .461 .483 .558 .972 .59 .471
OBSTACLE BRIGHTNESS - (FT-L) .04 .05 .145 .093 .084 .084
GLARE - (FT-L) .095 .123 .061 .084 .067 .086
RELATIVE VISIBILITY 1.92 1.85 2.20 1.88 2.10 1.90
RELATIVE EFFECTIVE ILLUMINATION - 25 22 41 23 33 29
SAME AS STATION #1.
OBSERVER DIRECTION
0.5 MH.
CURB
3MH (90FT.)
1 MOUNTING HEIGHT - 30 FT.
2 OBSERVER POSITIONS ARE 7MH. (210FT.) DISTANT FROM STATIONS.

Figure B. Tabulation of visibility factors calculated for two types of fluorescent luminaires at a spacing of 90 feet.

Fig. B shows a tabulation of visibility factors we calculated recently for two types of fluorescent luminaires at a spacing of 90 feet. In spite of the closer spacing, the average effective illumination is not appreciably more than that using the authors' ideal luminaire at a spacing of 210 feet.

Fig. C shows the calculated relative visibility and relative effective illumination based upon the authors' ideal luminaire. The relative visibility is 1.55 under the luminaire, 1.89 at a distance of 60 feet, and 2.18 at a distance of 120 feet. On the Reid-Chanon evaluator scale this gives an average relative effective illumination of approximately 25, which classifies this type of lighting for extra-heavy traffic streets.

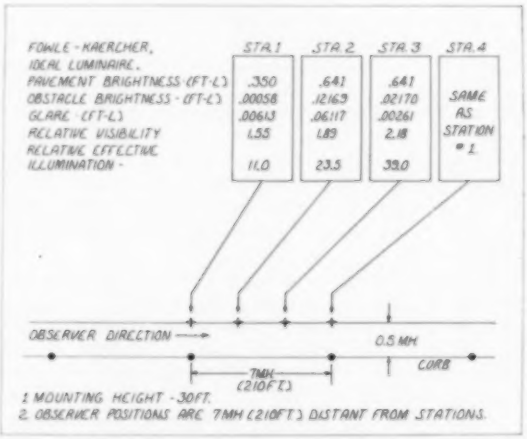

FOWLE - KAERCHER, IDEAL LUMINAIRE.
STA. 1
STA. 2
STA. 3
STA. 4
PAVEMENT BRIGHTNESS (FT-L) .350 .641 .641
OBSTACLE BRIGHTNESS - (FT-L) .00058 .12169 .02170
GLARE - (FT-L) .00613 .06117 .00261
RELATIVE VISIBILITY 1.55 1.89 2.18
RELATIVE EFFECTIVE ILLUMINATION - 11.0 23.5 39.0
SAME AS STATION # 1
OBSERVER DIRECTION
0.5 MH
CURB
7MH (210FT.)
1 MOUNTING HEIGHT - 30FT.
2 OBSERVER POSITIONS ARE 7MH (210FT.) DISTANT FROM STATIONS.

Figure C. Calculated relative visibility and relative effective illumination based on authors' ideal luminaire.

My negative criticisms of this paper are, first, that there are no data or calculations shown from which these conclusions are made. Second, at about 125 feet from the lighting unit, the brightness of the luminaire when viewed at high speeds from within today's automobiles might be very annoying. Third, it would seem that the drop-off in pavement brightness at distances between 90 and 125 feet from the luminaire would result in a very spotty effect. And, last, I am curious to know why the authors made comparisons of their luminaire with residential types.

M. E. KECK:* I was very happy to see a paper devoted to the subject of theoretical light distributions for street lighting, since this subject seems to have been neglected since the papers of Sweet and Rolph in 1927.

I am sure that if each member of the IES Roadway Committee were to be asked to prepare, from the technique described in this paper, a theoretical distribution curve and if, under even the most hypothetical conditions, each one could find the time to compute such a distribution, I believe that we would still have as many different proposed theoretically perfect light distributions as there are members of the committee.

I believe that one of the greatest needs in street lighting is to reach practical agreement on the theoretical light distribution for which we are striving. If this paper does no more than to start all of us giving greater consideration to solving this problem, it will have accomplished its objective.

One of the most difficult compromises in preparing such a theoretical distribution involves the decision as to the relative proportion of light which should reach a given point from more than one contributing luminaire. I feel that the authors have neglected this point, since it is possible to prepare an infinite number of different spherical isocandle charts from a single isolux plot merely by changing the proportion of light to reach each point from the various contributing luminaires.

I concur with the basic method proposed by the authors and am a little surprised that the distribution which they arrived at as indicated by Figs. 4, 8, and 9 comes out as close to luminaires now on the market as it does. I feel that it might be helpful if the authors would show us the utilization curve for luminaire "X," since it appears that they must have performed this calculation in the preparation of the paper.

I wish to congratulate the authors for their unbiased approach to the problem, and for their willingness to delve into such a controversial subject.

W. B. ELMER:** The authors deserve the gratitude of the entire street lighting industry for their courage in approaching this confused, difficult and neglected subject. Although their paper presents little new data, and no discoverable support for the new data presented, it is of value in that it states clearly and thoroughly the present conventional approach to the subject with all its contradictions and empiricism, and serves as a point of departure against which sound and logical philosophy can be built.

In the opening section, the authors recognize that "visibility" is the object of street lighting and suggest "visibility distance" as a specific parameter. They then sadly abdicate this excellent approach because of its admitted difficulty, and take refuge in the traditional and wholly unsatisfactory criterion of "illumination in footcandles."

After developing an idealized candlepower distribution for street luminaires on the basis of horizontal footcandles, with minimum limitations as specified in the American Standard Practice, they launch into a third section in which the results of this conventional approach are analyzed. In Table II, the performance of this idealized distribution is shown to give no better uniformity of pavement brightness than that provided by a radial wave reflector.

The important Fig. 7 is based on Figs. 5 and 6, showing the relationship between pavement brightness and angle of incident light in the first case, and the relationship between disability veiling glare and angle of incident light in the second. The source of this important data is not given — the curves are pulled out of thin air as far as the reader is concerned. Would the authors disclose fully the source of these curves? Secondly, would they specify the "observer viewing position with respect to a section of the roadway area" without which the curves are unintelligible?

The authors apply these curves in Fig. 7 not to their idealized light distribution, but to three actual luminaire installations. It is hoped that the authors will apply Figs. 5 and 6 to the idealized luminaire pattern as set forth in Fig. 4 and add the resulting pavement brightness characteristic to Fig. 7 to demonstrate how uniform a lighting result their ideal curve will produce.

Should this ideal curve fail to produce a smooth and uniform pavement brightness, it would appear quite simple to reverse the approach by drawing a horizontal line on Fig. 7 and to work backwards from this line through Figs. 5 and 6 to derive the vertical candlepower distribution necessary to produce uniform pavement brightness. From a brief study of the data, it would appear that more uniform visibility would be obtained if more light were projected near the luminaire to fill in the valleys out to three MH and less light at high angles to pull down the brightness peaks beyond this point.

Fig. 7 gives the ironical result that the primitive radial wave reflector produces more uniform pavement brightness and more uniform veiling glare than the more complicated and far more expensive modern luminaires with optical systems carefully engineered to give IES light distributions. Can this be one of the reasons why the lowly and despised radial wave reflector still persists down through the years?

In their conclusions the authors make a series of statements several of which are of highly doubtful validity, some quite incorrect, and none of which are supported by evidence brought forth in the paper. For example:

(1) It is *not* true that uniformity of horizontal illumination is involved in visibility distance; quite the reverse is true, since brightness is not proportional to illumination.

(2) Although it *is* possible, as the authors say, to derive a candlepower distribution required to produce a given illumination level and uniformity, this is of no value per se in achieving the authors' stated objective, greater (or uniform) visibility distance.

(3) It is not shown, as claimed, how greater visibility distance can be obtained from uniform pavement illumination. The data presented appear to prove the reverse quite conclusively.

(4) The statement that "low angle distributions should be used for shorter spacing ratios to obtain low glare high-footcandle roadway lighting" is solidly contradicted by the statement that "over-all net improvement in visibility distance is increased when using the longer spacing ratio, higher vertical angle distribution."

*Outdoor Lighting Engineering, Westinghouse Electric Corp., Cleveland, Ohio.
**Wheeler Reflector Co., Boston, Mass.

(5) Why high angle distributions are preferred for low illumination levels only is not explained or supported.

D. A. TOENJES:* This explanation of an approach to luminaire design will be of interest to street lighting users who wish to make their own comparisons of performance characteristics of different available luminaires. The characteristics described by the authors should not be expected to lead directly to any evaluation of general merit of a given luminaire, but they do help in selecting a luminaire for a specific installation.

Under "system design" the authors have touched on the differences in light distribution requirements. Can the authors suggest a tabulation or chart in which the requirements of different installation conditions might be related to the luminaire design variables? The roadway conditions themselves include the street width, brightness of the surround, traffic speed and density and complicating factors such as intersections and merging roadways and curves and hills. Is there some graphical or systematic way to relate these to the controllable conditions such as spacing, mounting height, candlepower distribution, luminaire size and brightness, and light output?

Although many such relationships are discussed throughout the paper, they might be more readily understood by means of consolidation into charts or tables.

A. W. FOWLE AND R. L. KAERCHER:** We appreciate the many points brought up in the discussion of this paper. Unfortunately, however, the comments made so enlarge the subject that space does not permit a detailed reply to all. We will confine our rebuttal to answers to specific questions and requests for additional information.

Mr. Rex asked for our definition of "visibility distance." This is given in the first sentence of the fifth paragraph of the paper. It seemed to us at the time of writing the paper and again while reviewing the discussions that there is a need to spell out precisely, define and categorize the terminology which we are all using in connection with the over-all experience of "vision" under roadway lighting.

In selecting "visibility distance" as our criterion, we did so with the realization that it is only a part of the over-all aspect of "visibility." "Visibility" as such does not yet have a precise enough meaning to be calculated or measured or rated by a single number. On the other hand, "visibility distance" *can* be measured and *can* be calculated, if reflection factors, object size and incident illumination are known.

Visibility distance does involve brightness contrasts, as Mr. Rex pointed out. Furthermore, for given reflection factors of object and background, the *brightnesses* of the object and background are directly dependent on the illumination on them. Illumination on any plane at any given point can, in turn, be directly related to the *horizontal footcandle* criterion.

We are glad that Mr. Wall has brought out the point that "visibility" and the "effectiveness of street lighting" are not entirely dependent on the factor of horizontal footcandles and their uniformity. We certainly agree, and our paper is not meant to dispute this, because there is a recognized difference between "visibility" and "visibility distance." As mentioned previously, the latter is dependent (all other factors being equal) on the illumination in the roadway area. In order to tie this down to something definite that can be readily understood and calculated, we feel the choice of the horizontal footcandle (which can be easily related to the horizontal geometry of the street) is the most practical one.

In arriving at the candlepower distribution shown, it was necessary to determine, for every point on the street, the relative proportion of light flux contributed by each luminaire. For a given system design and *illumination uniformity*, there is not a great deal of deviation from the distribution arrived at without obtaining a light distribution that would be impractical from the standpoint of maximum candlepower, distribution of candlepower, etc. If, for example, the maximum and minimum footcandle values were made to come out in locations exactly the reverse from the way they would be on the roadway with the ideal distribution, the shape of the light distribution would become so drastically altered that it could not be produced with a practical luminaire. Furthermore, it would be undesirable from the standpoint of the other aspects of pavement brightness and veiling glare. Minor deviations are possible, but these will affect the final results of average horizontal footcandles, uniformity, veiling glare, roadway brightness, etc.

The 72½-degree angle of maximum candlepower resulted from the proportioning of light flux to produce the desired uniformity for the assumed system design. Using other system designs, average intensities and uniformity would change the distribution of required candlepower.

The determination of the light distribution was independent of any lamp size that might be used and was obtained by computing the candlepower required to produce the amount and pattern of illumination that was established for this case. The resulting spherical isocandle chart in Fig. 4 of the paper can be used to produce an isofootcandle chart. This is shown in Fig. D. To answer Mr. Keck's request for a utilization curve, we have related our results to a lamp with 20,300 lumens output and arrived at the utilization

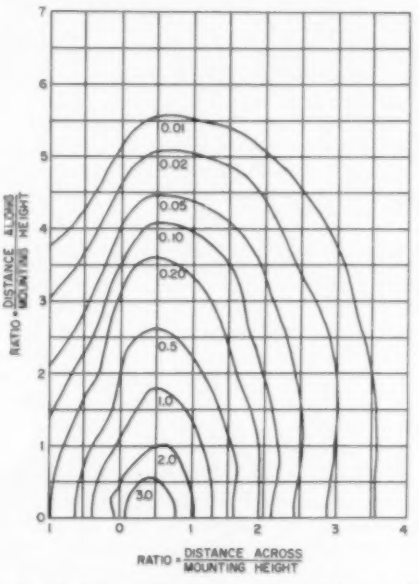


Figure D. Isofootcandle chart produced from spherical isocandle chart in Fig. 4 of paper.

*Lamp Division, General Electric Co., Cleveland, Ohio.
**Authors.

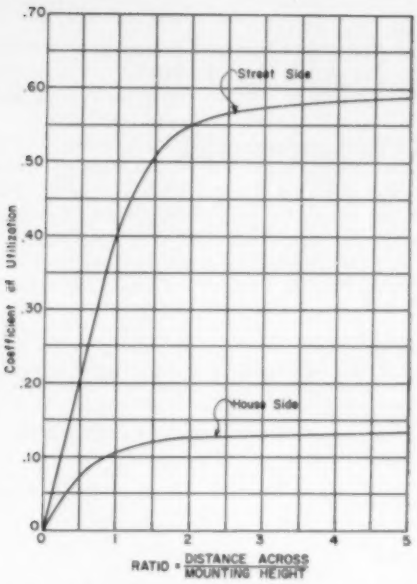


Figure E. Utilization curve for a lamp with 20,300 lumens output.

curve in Fig. E. Larger or smaller lamp sizes would produce correspondingly lower or higher utilization figures.

All computations, including those for brightness data, were omitted due to lack of space. Roadway brightness values were computed from the same pavement reflection data and methods used by Reid and Chanon.[1] This is the best available until such time when we will have more complete statistical information on pavement reflection properties. Disability veiling brightness was computed using the standard formula, $DVB = (10 \pi Ev)/\theta^2$. In both cases, the observer was at a fixed location — on the roadway — not elevated at any time. The light source was moved in an arc about the section of pavement being observed in Fig. 5, or about the observer looking ahead along the normal line of sight in Fig. 6. These two curves were developed to show the relationship of these brightness phenomena to the *angles of candlepower emission* (not necessarily with respect to horizontal footcandle results in a roadway system).

Candlepower at the higher angles has a negligible effect on horizontal illumination. However, it has a significant effect on producing pavement brightness and veiling glare, as shown in Figs. 5 and 6. Because of this, it is important to carefully control the candlepower at high angles so that these contradicting factors will be properly balanced. It is true that with a fixed luminaire position, as the emission angle is raised, the resultant pavement brightness value decreases, due to the rapid increase in distance from the luminaire. It is fortunate that the roadway has a characteristic which produces the results in Fig. 5, as this compensates for the loss due to increased distance from the luminaire.

We are happy that Mr. Elmer pointed out the "primitive radial wave reflector" is a good performer. This, of course, is at *close spacings* as shown in Fig. 7 and Table II. The "complicated and expensive modern luminaires with optical systems carefully engineered to give IES light distributions" are, as noted in Table II, able to use larger lamps and produce *over twice the pavement brightness results* at *longer more economical* spacings. With typical average annual utility rates of $30 for the radial wave reflector and $48 for the carefully engineered optical system, we find the following saving:

Luminaire C (Radial Wave)	43 units/mile, $30 each =	$1290
Luminaire A (High Angle Type I)	18 units/mile, $48 each =	846
	Saving per mile	$ 426

The optical assembly is only a small part of the cost of the lighting system, ranging from two to ten per cent (except for fluorescent luminaires). Often, the difference between the "primitive" radial wave type and a well-designed optical assembly is less than five per cent of the system

TABLE F — The Effect of Variable Luminaire Factors on Visual Elements in Roadway Lighting.

	VISUAL ELEMENTS											
	Footcandle Intensity		Footlamberts Brightness					Uniformity			Glare	
			Pavement				Object	Footcandles		Foot-lamberts		
Variable Luminaire Factors	Horiz. Plane	Vert. Plane	Concrete Dry	Concrete Wet	Asphalt Dry	Asphalt Wet		Horiz. Plane	Vert. Plane	Bright-ness	Veiling	Dis-comfort
Area and Brightness (Constant Output)	3	3	2	1	2	1	2	3	3	2	3	1
Candlepower Above 60° Vertical (Within 30° Lateral to Curb)	2	1	1	1	1	1	1	1	2	1	1	1
Candlepower Below 60° Vertical	1	1	1	2	1	2	1	1	2	2	2	2
Mounting Height	1	1	1	1	1	1	1	1	1	1	1	1
Spacing	1	1	1	1	1	1	1	1	1	1	1	1
Arrangement (Staggered Opposite One Side)	2	2	2	2	2	2	2	1	1	1	2	2
Location (Transverse to Street)	2	2	2	1	1	1	2	2	2	1	1	1

KEY:
1 — Major Effect
2 — Minor Effect
3 — No Effect

cost. It should become quite obvious that if we are really conscious of giving the taxpayer his money's worth, we cannot afford to do less than provide the most efficient and effective optical assemblies.

The illumination and brightness results from the ideal curve asked for by Mr. Elmer, are shown in Table II and Fig. 10, respectively. The observer path and longitudinal roadway lines used for brightness computations were "in line" and 15 feet out from the luminaire. The results shown are the combined averages of the data along these roadway lines.

As to Mr. Wall's comment on "brightness of the luminaire," this would depend on luminaire area for which no data have been derived. We did not design a luminaire, we merely developed a candlepower distribution which would be given to the luminaire designer to produce. As far as veiling glare is concerned, which is independent of luminaire area, at the 125-foot distance, the candlepower in the direction of the observer ranges from 1500 to 2500 candlepower, depending on the transverse location of the observer on the roadway. This is low, as pointed out in Item 3 under the section on "Results."

In Fig. 7 and Table II, "residential type" luminaires were used in order that comparisons could be made with other types of *distributions* and you will notice they are made on a "per footcandle" basis in Table II.

Mr. Toenjes' request for a chart to relate different installing conditions to luminaire design variables reminds us of a similar chart recently presented by Edman,[2] which we include here (Table F). While this does not completely spell out the *requirements* of luminaire design, it does summarize the effects that luminaire factors have on the visual elements in roadway lighting. A more thorough discussion of each of these is given in Edman's paper.

References

1. Reid, K. M., and Chanon, H. J.: "Evaluation of Street Lighting," *Transactions of the Illuminating Engineering Society*, Vol. XXXIV, No. 10, p. 1209 (December 1939).
2. Edman, W. H.: "An Analysis of Visual Elements in Roadway Lighting," *American Institute of Electrical Engineers Applications and Industry* (November 1958).

Golfing Under Mercury

Uniform light distribution with an absence of bright spots and shadows is obtained on this Amarillo, Texas miniature golf course by mounting 15 street lighting luminaires 26 feet above ground on the high outer edge of the area. The luminaires are equipped with 1000-watt BH15 golden white fluorescent-mercury lamps rated at 52,000 lumens. "Fill-in" lighting in the center of the course is from six 400-watt JH1 golden white fluorescent-mercury lamps, mounted two per pole, thirty feet above ground. This additional lighting in the deepest part of the excavated area helps to maintain the uniformity of the light distribution.

Since the long distances involved in underground wiring (area of the course is 115,646 square feet) presented a problem of excessive voltage drop from the power source to the furthest light, it was decided to use 440-volt circuits and ballasts of the same voltage.

Illumination level on the course averages five footcandles maintained, and there is sufficient back-spill of light to adequately illuminate the adjacent parking lot. Maintenance of the system is expected to be practically nil, since the life of the lamps extends over several seasons of use.

Keith E. Taylor, Westinghouse Electric Supply Co., Amarillo, Texas, took first prize in Class II of the Panhandle Chapter's 1958 My Most Interesting Lighting Job contest with this installation, and later placed third in the Southwestern Region's contest.

Computation of Relative Comfort and Relative Visibility Factor Ratings for Roadway Lighting

By CHARLES H. REX

Most of the seventy million drivers in the United States make night use of their tremendous multi-billion dollar investment in streets, highways, automobiles, trucks and buses. The value received from this investment in pleasant and efficient night movement of traffic is of great social and economic significance.

Roadway lighting for night living with automotive transportation presents an urgent public welfare opportunity which is receiving increased attention by officials, engineers, technicians and those engaged in traffic and visual research. Progress in more efficient, pleasant and attractive night driving conditions is being aided by this rapidly increasing recognition and knowledge of the benefits of roadway lighting.[1-4, 15, 19, 21, 22, 24]

Traffic Benefit is Contingent Upon Seeing Effectiveness

New traffic benefit ratings will evolve from current and future studies of operational night traffic capacity factors such as headways, vehicle formations, speeds, lane use and avail of passing opportunities. These and other traffic benefits such as accident prevention, convenience and comfort are *contingent upon the effectiveness* of the roadway lighting in producing good seeing, as diagrammed in the upper portion of Fig. 1.

"Figure of merit" studies of the traffic benefit derived from roadway lighting have the support of organizations including:

Highway Research Board N.R.C. Committee on Night Visibility,
Institute of Traffic Engineers Committee on Roadway Lighting,
United States Bureau of Public Roads,
Connecticut State Highway Department,
Texas Highway Department,
Illuminating Engineering Society Committee on Roadway Lighting,
Illuminating Engineering Research Institute.

In addition, the U. S. Congress has authorized a Highway Safety Study for the comprehensive investigation and analysis of accident causes. Northwestern University and eleven State Highway Departments are engaged in these studies. In the instances where night accidents occur in spite of roadway lighting, the effectiveness of the lighting should be rated in terms of its major seeing factors as shown in Fig. 1.

Urgent Need for Seeing Factor Ratings For Roadway Lighting

It is increasingly evident that ratings for the effectiveness of roadway lighting in producing good seeing conditions are urgently needed. The seeing factors — visual comfort, visibility — along with conditions for driver alertness, as shown in upper portion of Fig. 1, are the objectives of the designer's skill in balancing the contributing factors shown in the lower portion of this diagram.

Those responsible to the motoring public for the successful night operation of traffic are interested in readily comprehensible objective ratings for the seeing factor effectiveness of roadway lighting.

Fig. 2 shows the computed relative visual comfort and relative visibility ratings for a representative roadway lighting system. Such dual ratings present a significant simplification for those who represent the roadway user and those who desire to know the relative seeing factor effectiveness of roadway lighting systems.

Seeing Factor Ratings Serve as A Basis for Traffic Benefit Ratings

The importance of a good relative visual comfort rating compared with or accompanied by a high relative visibility rating will evolve from correla-

A paper presented at the National Technical Conference of the Illuminating Engineering Society, August 17-22, 1958, Toronto, Ont. AUTHOR: Outdoor Lighting Department, General Electric Co., Hendersonville, N. C. This paper accepted by the Papers Committee of IES as a Transaction of the Illuminating Engineering Society.

Figure 1. Data, emphasis, control and balance of factors shown in the lower portion of this diagram produce the visual comfort and visibility factors in seeing. These seeing factors and driver alertness produce the improvement in traffic comfort, convenience and safety essential for efficient night operation of our public investment in automotive transportation facilities.

tion with the effectiveness ratings in terms of the traffic benefit produced. Both seeing factor ratings and traffic benefit ratings will also indicate how much better good roadway lighting is as compared with poor roadway lighting or none.

Ratings for Visual Benefit

The seeing benefit of roadway lighting may now be presented in readily comprehensible dual ratings shown in Fig. 2. The numerical ratings may be in terms of the average effectiveness of a system of luminaires over a cycle of variations experienced by the driver moving along the roadway:

Average Relative Visibility	1.8
Average Relative Visual Comfort	0.27

Or, the minimum effectiveness ratings for the roadway lighting system may be more significant:

Minimum Relative Visibility	1.6
Minimum Relative Visual Comfort	0.11

The minimum rating driver position and brightness station distance along representative longitudinal roadway lines are shown in Fig. 12 and Fig. 15. For this computation example the relative visibility is at a minimum when viewed from a driver position of minimum relative visual comfort. When this correlation pertains and only minimum ratings are desired, computation could be reduced from sixteen station-positions to one.

Scale of Relative Visibility

The computed relative visibility ratings in this paper are based upon the scale of the currently available Luckiesh-Moss Low-Range Visibility Meter, used in the visibility studies by Reid and Chanon.[5] They defined the threshold as follows:

> "A visibility of 1.0 (as applied to seeing for safety on streets) is defined as mere discernment of a one-foot obstacle of zero brightness, on a background having a substantially uniform brightness of approximately 0.01 foot-lambert, by a stationary observer with normal vision standing 200 feet away at fixed attention with no source of direct glare in the field of view. When an obstacle of this description is so discerned through the Luckiesh-Moss Visibility Meter the reading is unity."

A rating of 1.0 is for all practical purposes a base reference[9] or threshold pertaining to favorable static conditions.

Other instrumentation[9,10,11] and the necessary correlations for visibility factors such as pavement brightness, obstacle brightness, disability veiling brightness and fluctuations thereof should be available soon.

Future ratings may be relative to the visibility *required*[11] for typical night driving conditions. Evaluation of the driver's visual task under dynamic conditions may produce a Datum visibility

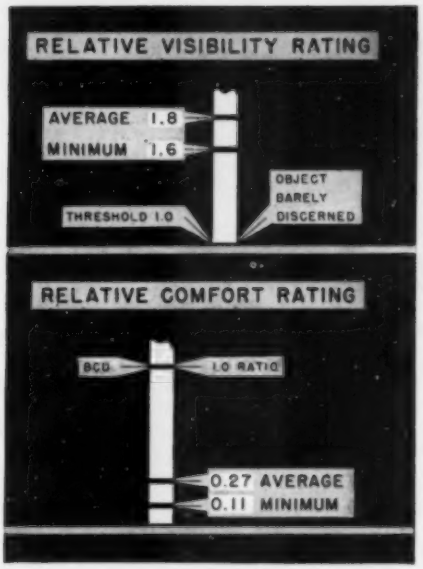


Figure 2. Example of seeing factor ratings for a representative roadway lighting system. Relative visibility ratings may now be accompanied by computed ratings for relative comfort. The visual comfort rating is relative to the sensation which would be at BCD, the average borderline between comfort and discomfort, for the system of luminaires and the lighted roadway. Analysis of experimental data will indicate the per cent of motorists who would be comfortable with roadway lighting having a rating ratio such as 0.27 or 0.11.

level or reference which will be well above the threshold previously described as 1.0. For example, assume that the Datum visibility required could be correlated to indicate that a Luckiesh-Moss Visibility Meter rating of 5.0 is essential. Then the Fig. 2 minimum relative visibility rating of 1.6 would compare in the scale ratio of 1.6/5.0 or 0.32. If the threshold 1.0 is subtracted from both numbers, the ratio to that required would be 0.6/4.0 or 0.15.

Such desirable Datum or objective rating might be approaching the "aggregate visual safety factor" described by A. J. Harris.[15]

Visual Comfort Rating Relative to BCD

Visual comfort ratings such as those shown in Fig. 2 are relative to the driver-observer sensation which would be at BCD, the borderline between comfort and discomfort for the representative system of luminaires and the lighted roadway. The BCD, designated as 1.0, is based upon a geometric average of the observers used in laboratory studies by Putnam-Faucett[7] and Putnam-Bower.[6] If a sufficient number of observers were uniformly distributed above and below the BCD we might say that 50 per cent of the observers would be comfortable driving under lighting having a rating of 1.0. Analysis of experimental data involving a sufficient number of observers will also indicate the per cent of motorists who would be comfortable driving under roadway lighting having a relative visual comfort rating of 0.27 or the 0.11 minimum.

Putnam-Bower[6] recommended Visual Comfort Index, VCI, analysis and future work for rating roadway lighting.

By rating roadway lighting in terms of relative visual comfort as shown in Fig. 1 and Fig. 2, instead of discomfort, several additional advantages are obtained including:

(1) Positive approach to the problem of improving the *quality* of roadway lighting.

(2) An ascending numerical scale whereby improvement is accompanied by a higher number.

(3) Relative visual comfort is consistent with one of the principal objectives of motor vehicle transportation, *i.e.*, the improvement of all conditions affecting motorist comfort. For example:

(a) *"This construction is for your future comfort and safety. Drive carefully,"* featured on detour signs erected by the Virginia Department of Highways.

(b) A statement by Joseph P. Barnett, Assistant Deputy Commissioner, U. S. Bureau of Public Roads. "Intangible benefits are possibly greater use of the highway at night, some increased ease of policing, pleasant appearance, and greater comfort in driving, although many challenge the last benefit."

(4) We regard this paper as the beginning of providing computed visual comfort ratings for roadway lighting.

Over-all comfort and driver conditions for night traffic use and movement along roadways includes visual comfort. Relative visual comfort ratings for roadway lighting are essential.

The relative visual comfort ratings, Fig. 2, are based upon an average field brightness of 1.0 for the lighted roadway. As shown in Fig. 1, the over-all field brightness includes the brightness of the pavement. The maximum and average pavement brightness for the computation example is 0.71 and 0.45 footlamberts respectively.

Advantages of Computed Ratings

Computation of seeing factor ratings, such as those shown in Fig. 2, has many advantages also recognized abroad,[13,14,15] including:

(1) Prediction of the effectiveness of roadway lighting in readily understandable terms of road-

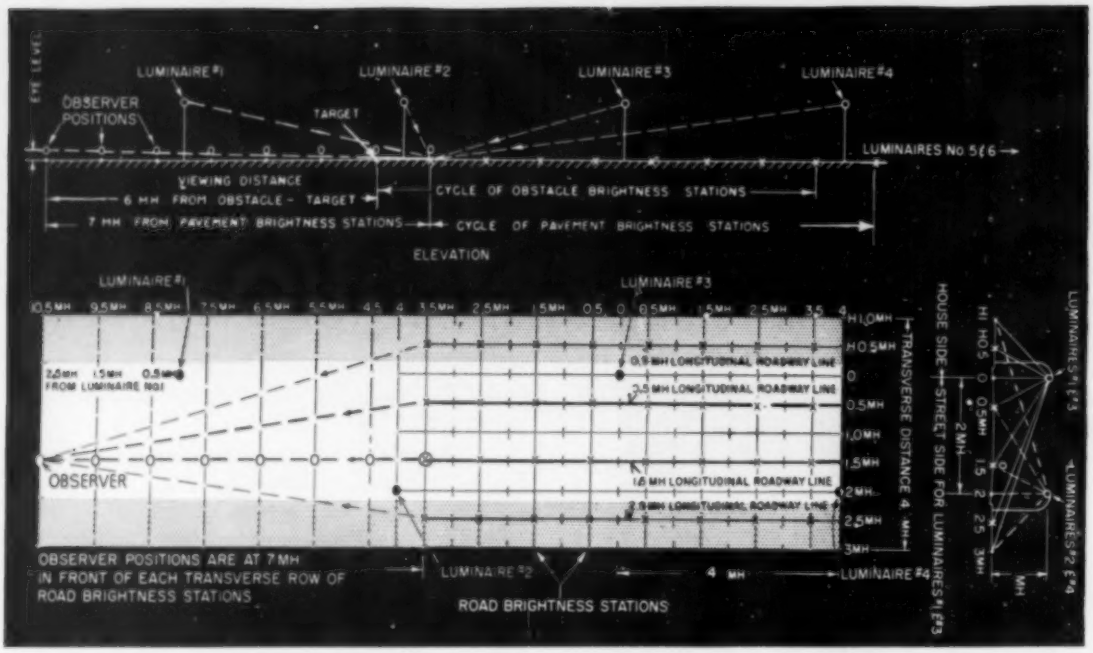


Figure 3. Representative roadway, lighting layout and conditions for computation of relative visibility, pavement and obstacle brightness. Driver-observer movement and view-direction is from left to right along 1.5 MH roadway line. Pavement brightness stations and luminaire No. 3 are considered basic reference points. Stations along longitudinal roadway lines at transverse distance of 0.5 MH and 1.5 MH are assumed representative of the traffic-used portion of the roadway. Targets for obstacle brightness at 4.5 MH longitudinal distance are seen in contrast with the pavement brightness 1.0 MH beyond, at 3.5 MH.

way user benefit derived. This is also of interest to those who decide how much roadway lighting will be installed or improved.

(2) Application and luminaire performance variables may be explored, evaluated, and controlled in design for optimum over-all efficiency.

(3) Comprehension of objectives will be improved, complexity reduced, and standardization possibilities revealed.

(4) Progress in dynamic visual research under night driving conditions will be encouraged by a method for the use of laboratory and outdoor data now available and to be made available later.

(5) Time will be conserved. Computation facilitates ratings without the delays, uncertainties, and interferences that may arise in field testing. The use of high-speed computer techniques is obviously feasible and desirable. With example ratings available for typical roadway lighting systems, others may be estimated by interpolative judgment.

(6) The seeing factor significance of luminaire performance data becomes readily apparent. An example is the control of the candlepower distribution along eye-level longitudinal roadway lines, shown in inclined plane polar or rectangular coordinates, which improves both the per cent visibility loss due to DVB (disability veiling brightness) and the relative visual comfort. Increasing the candlepower along roadway lines at pavement level increases the pavement brightness, obstacle brightness and the field brightness factor in relative visual comfort. Even footcandles, horizontal and vertical, may be conveniently appraised and/or combined on the basis of multiple of mounting height (MH) stations, as used in this computation method.

(7) The interest of technicians will be increased. This includes those who now devote considerable time to the engineering computation of electrical and mechanical problems in connection with roadway lighting systems.

Conditions for Computation Example

The example computations described in this paper are based upon the following conditions:

(1) Available data.[2, 4-7, 16, 21, 24]

(2) A representative roadway lighting layout, shown in Fig. 3 and Fig. 7, with luminaire spacing

staggered 120 feet, or 4 MH. Luminaire No. 3 is considered the reference for longitudinal and transverse distance in MH.[2-4, 16]

(3) The two longitudinal roadway lines, at transverse distance of 0.5 MH and 1.5 MH, respectively, are assumed to be representative of the traffic-used pavement areas of the typical roadway. The driver eye-level path line is at 1.5 MH.[2, 4, 16]

(4) Pavement level brightness stations and driver-observer viewing positions are spaced along the roadway lines at the longitudinal distance of 0.5 MH or 15 feet apart. The pavement brightness stations are reference points. The driver-observer views the pavement brightness stations from a distance of 7 MH. This viewing angle is about 1.2 degrees above the pavement surface. At the angle of driver view the mid-vertical portion of the one-foot diameter target or obstacle, at longitudinal distance of 6 MH, projects on to approximately line up with the pavement brightness station being viewed at a distance of 7 MH. This 6 MH versus 7 MH longitudinal distance, for obstacle-pavement brightness comparison, approximates outdoor full-scale testing conditions.[2, 3, 16]

(5) Hypothetical luminaire inclined plane candlepower distributions[2-4] along representative longitudinal roadway lines, at pavement level, also at driver eye-level. The eye-level is 25.7 feet below luminaire light center or 4.3 feet above the pavement. Such candlepower data may be estimated from an isocandle diagram[4, 16, 23, 24, 26] or obtained directly from a photometer.[27] The data may be

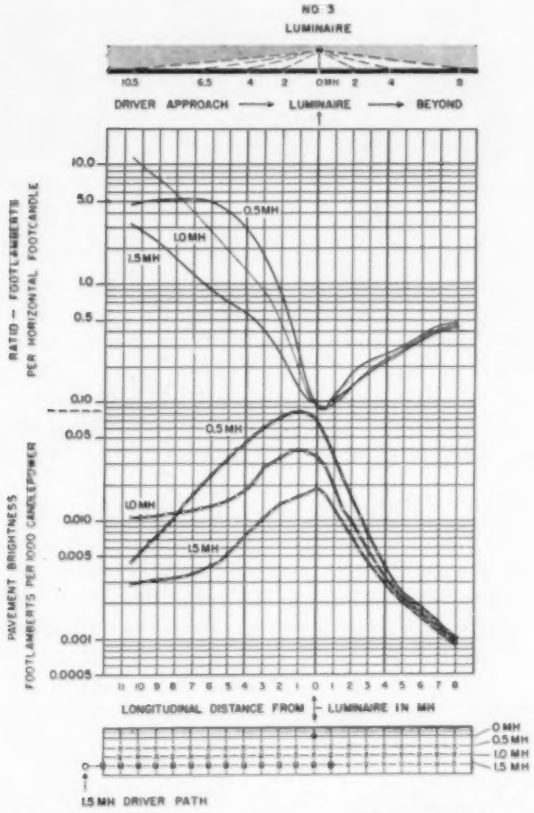


Figure 4. The pavement brightness, *PB*, produced per 1000 candlepower from a single luminaire which is at the driver's left is shown in the lower portion of this diagram. The longitudinal distance of driver observation from each pavement brightness station is about 7 MH or 210 feet. The stations are 0.5 MH or 15 feet apart along the designated longitudinal roadway lines. Data are by Reid-Chanon for traffic-used asphalt pavement. The curves on the upper portion of the diagram show the ratio of pavement brightness per horizontal footcandle produced by the luminaire at the pavement stations.

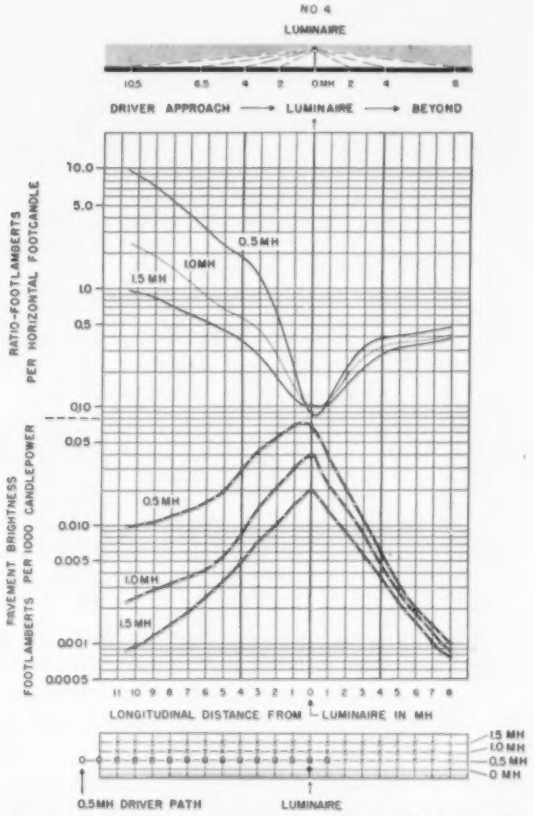


Figure 5. The candlepower from the single luminaire on the driver's right and at distances greater than 1.0 MH on the approach side of the luminaire is less effective than candlepower from luminaire No. 3 (Fig. 4) in producing pavement brightness at stations along the 1.0 MH line along the center of the roadway. With the staggered spacing used for the computation example, pavement brightness along the 0.5 MH roadway line in this illustration is combined with that along the 1.5 MH roadway line in Fig. 4.

tabulated for pavement stations and eye-level positions at 0.5 MH distance intervals and may also be shown on rectangular or polar distribution diagrams.[2-4]

(6) Representative asphalt pavement, traffic-used for eight years, 8 per cent diffuse reflectance.[5] Pavement brightness constants are derived from original data.[3,4,16] Brightness measurement conditions were to ¼ scale,[5] *i.e.*, 5-inch instead of 20-inch diameter source, 6¼-foot instead of 25-foot mounting height. Computation has converted data to 30-foot mounting height.[4,16] Luminaire candlepower and pavement brightness constants at longitudinal distances ranging from 10.5 MH on approach side to 8 MH beyond each luminaire, as shown in Figs. 4 and 5.

(7) Diffuse obstacle target, 8 per cent reflectance, one foot in diameter,[4,5,16] using luminaire candlepower and obstacle brightness constants up to 10.5 MH beyond the luminaire.

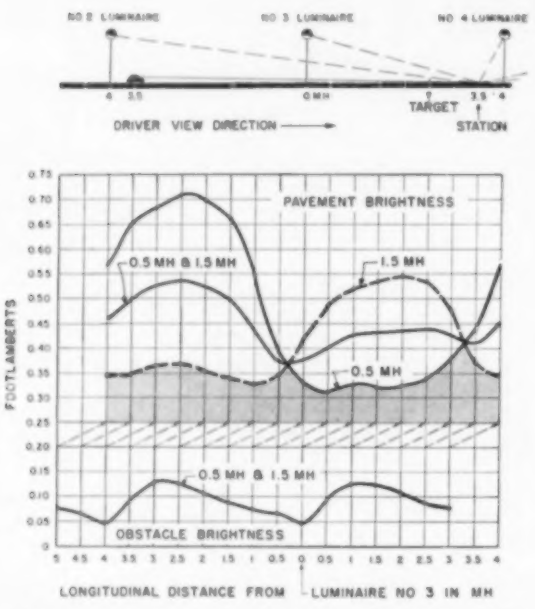


Figure 6. The combined pavement brightness, ΣPB, produced by the representative roadway lighting system varies as shown at stations along the 0.5 MH or 1.5 MH roadway lines. The ΣPB pavement brightness curve designated 0.5 *and* 1.5 MH is the transverse average of brightness at the two stations at each longitudinal distance. As indicated by the shading, the minimum pavement brightness, alternatively 1.5 MH then 0.5 MH, may be most significant. The obstacle brightness ΣOB is the transverse average for stations along the 0.5 *and* 1.5 MH roadway lines. Obstacle brightness is correlated with pavement brightness at longitudinal distance 1 MH beyond the obstacle brightness targets. The reflectance of the pavement and of the obstacle is the same, 8 per cent.

(8) At longitudinal distances *less* than 3.5 MH, the light from each luminaire[4,18] is cut off from driver eye-level positions by the top of the auto windshield. Luminaire eye-level candlepower, brightness and DVB constants are used for driver positions at longitudinal distances ranging from 3.5 MH to 15 MH (450 feet) on the approach side of each luminaire, as shown in Fig. 8.

(9) The projected luminaire source area is assumed to be 100 square inches when viewed by the driver from position distances such as 15 MH. To be typical of generally-used, modern roadway lighting luminaire, the projected area is appropriately and gradually increased to 130 square inches at 3.5 MH viewing distance.[2,3,16]

(10) The average illumination on the pavement from the luminaire layout shown in Fig. 3 and Fig. 7 may be about 1.3 footcandle. This is based upon an assumed 25,000-lumen lamp[4] and the utilization shown in Fig. 13 of the American Standard Practice for Street and Highway Lighting.[24]

Computation of Relative Visibility and Factors

The computation of relative visibility ratings and data with respect to visibility factors involves combining the effect produced by several luminaires on a *succession* of brightness *stations* along the pavement roadway lines as viewed from related driver positions along a representative roadway, Fig. 3. Thus some of the variations and fluctuations with driver movement along the roadway are revealed.[4,5,13,15,16,25]

Pavement Brightness

Pavement brightness at each station is computed using constants[16] per 1000 candlepower which have been developed from Reid-Chanon data.[4,5] Using these data the pavement brightness per luminaire at each station is:

$$PB\ (\text{Pavement Brightness}) = \frac{\text{Luminaire Candlepower}}{1000} \times \text{Pavement Brightness Constant}$$

The pavement brightness constants for stations along the 1.5 MH, 1.0 MH, and 0.5 MH roadway lines per 1000 candlepower from luminaires along each side of the roadway are as in Figs. 4 and 5.

The pavement brightness per horizontal footcandle is included in Figs. 4 and 5 primarily for information and possible alternative computations. The pavement brightness produced per horizontal footcandle depends upon the direction of incident light from each luminaire in relation to a driver-observer viewing position. The result of illumina-

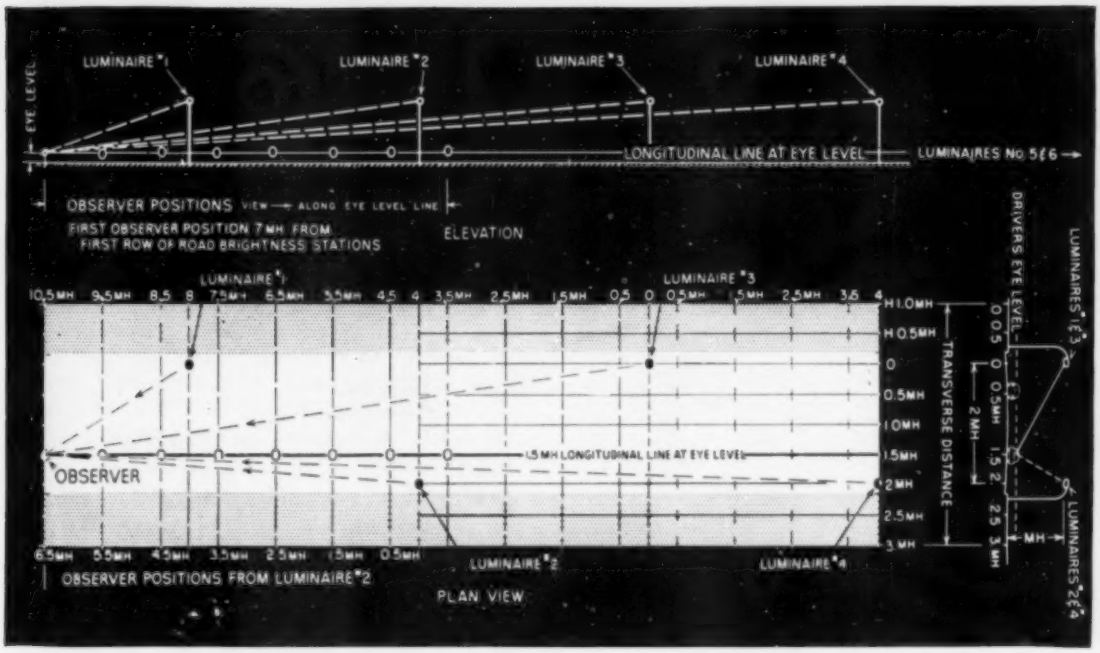


Figure 7. Combined relative comfort and per cent loss of relative visibility due to disability veiling brightness is computed for a series of driver-observer positions along the longitudinal eye-level line, also assumed to be the driver's line of sight. This line is 25.7 feet below the luminaire light center. The driver eye-level line path is at a transverse distance of 0.5 MH with respect to luminaires on the driver's right, such as No. 4, and at 1.5 MH with respect to luminaires on the driver's left, such as No. 3. The effect of inclined plane longitudinal eye-level candlepower from several luminaires, as far as 15 MH from each driver position, is included in computations.

tion at each station from each luminaire should be computed separately, then combined for the effect of several luminaires.

The use of the pavement brightness-candlepower constants and the additive combining of the brightness at each station produced by each luminaire may be tabulated. Table II shows the computation of combined pavement brightness along the 0.5 MH roadway line. Refer to Fig. 3.

The longitudinal distance relation of each pavement brightness station with respect to each luminaire is indicated in Table II, Rows 1, 5, 9, 13, 17, 21, and 25.

The 0.5 MH constants, shown in Fig. 4, for luminaires such as No. 3, No. 1, and No. 5, are inserted in Table II, Rows 2, 10, and 22. The inclined plane luminaire candlepower for stations along 0.5 MH longitudinal roadway line is tabulated in Rows 3, 11, and 23 for the corresponding distances. The luminaire candlepower/1000 is multiplied by the constant to obtain the pavement brightness produced at each station by each luminaire.

Luminaires such as No. 2, No. 4, No. 0, and No. 6 are at transverse distance of 1.5 MH with respect to the 0.5 MH roadway line. The 1.5 MH constants shown in Fig. 5 are used in Table II, Rows 6, 14, 18, and 26 accompanied in the next rows by the 1.5 MH roadway line luminaire candlepower. Thus computation provides the pavement brightness at each longitudinal distance from each luminaire.

The *combined* pavement brightness ΣPB for each station along the 0.5 MH representative roadway line is the sum of the pavement brightness numbers in each column. This is shown in Row 29 of Table II.

The combined pavement brightness ΣPB at each station along the 1.5 MH roadway line, shown in Fig. 3, is obtained from Table I by similar procedure. Table I is omitted. It will be furnished by the author upon request.

The 1.5 MH *and* 0.5 MH combined pavement brightness is the transverse average of the combined pavement brightness ΣPB at each longitudinal distance along the two roadway lines as shown in Row 31 of Table II, and Fig. 6. The longitudinal average pavement brightness over a cycle of luminaire spacing as shown at the bottom of Table II is 0.45 footlambert.

Fig. 6 shows the plot of combined pavement brightness ΣPB at successive stations along the 1.5 MH (from Table I) and the 0.5 MH (from Table II) representative roadway lines. The shaded minimum for the two lines alternately 1.5 MH then 0.5 MH may be significant because it is the minimum at each distance along the roadway.

Obstacle Brightness

Table III shows the combined obstacle brightness ΣOB for target positions along the 1.5 MH roadway line. As indicated, the obstacle brightness at each station produced by each luminaire is computed:

$$OB\ (\text{Obstacle Brightness}) = \frac{\text{Luminaire Candlepower}}{1000} \times \text{Obstacle Brightness Constant}$$

The obstacle brightness constants are per 1000 candlepower[16] from the luminaires at specified locations. The obstacle brightness at stations along a roadway line at 1.5 MH with respect to luminaires such as No. 3, and at 0.5 MH with respect to luminaires such as No. 2 or No. 4, are tabulated

TABLE II—0.5 MH* Roadway Line Combined Pavement Brightness.

Row	Luminaire No. 2									Luminaire No. 3								Luminaire No. 4
1. Longitudinal Distance in MH from No. 3 Luminaire	4	3.5	3	2.5	2	1.5	1	.5	0	.5	1	1.5	2	2.5	3	3.5	4	
2. Pave. Br. Constant/1000 cp (0.5 MH)*	.0464	.0534	.0613	.069	.075	.080	.083	.080	.071	.052	.035	.023	.016	.011	.0077	.0053	.004	
3. Luminaire cp (0.5 MH)*	9750	10400	9900	8800	8050	7100	5500	3600	3100	3600	5500	7100	8050	8800	9800	10400	9750	
4. Pave. Br. No. 3 Luminaire (fL)	.4529	.5554	.5865	.6072	.6038	.5680	.4565	.2880	.2201	.1872	.1925	.1633	.1288	.0968	.0739	.0551	.0390	
5. Longitudinal Distance in MH from No. 2 Luminaire	0	.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	
6. Pave. Br. Constant/1000 cp (1.5 MH)**	.02	.0164	.0132	.0107	.0089	.0071	.0057	.0046	.0037	.003	.0024	.0018	.0016	.0011	.001	.00085	.00082	
7. Luminaire cp (1.5 MH)**	3800	4200	5500	7100	8050	9050	10400	12250	10350	8130	6900	5350	4375	3500	2900	2350	1950	
8. Pave. Br. No. 2 Luminaire (fL)	.072	.0688	.0726	.0760	.0708	.0643	.0583	.0564	.0383	.0245	.0158	.0096	.0070	.0039	.0029	.0020	.0016	
9. Longitudinal Distance in MH from No. 1 Luminaire	4	4.5	5	5.5	6	6.5	7	7.5	8									
10. Pave. Br. Constant/1000 cp (0.5 MH)*	.004	.0029	.0023	.0021	.0018	.0016	.0015	.0011	.0010									
11. Luminaire cp (0.5 MH)*	9750	7750	6400	5250	4300	3450	2750	2200	1750									
12. Pave. Br. No. 1 Luminaire (fL)	.0280	.0225	.0147	.0110	.0077	.0055	.0036	.0024	.0018									
13. Longitudinal Distance in MH from No. 0 Luminaire	8																	
14. Pave. Br. Constant/1000 cp (1.5 MH)**	.00082																	
15. Luminaire cp (1.5 MH)**	1950																	
16. Pave. Br. No. 0 Luminaire (fL)	.0016																	
17. Longitudinal Distance in MH from No. 4 Luminaire	8	7.5	7	6.5	6	5.5	5	4.5	4	3.5	3	2.5	2	1.5	1	.5	0	
18. Pave. Br. Constant/1000 cp (1.5 MH)**	.0015	.0016	.0018	.0021	.0025	.0028	.003	.004	.0049	.0058	.0071	.0087	.010	.012	.015	.017	.02	
19. Luminaire cp (1.5 MH)**	1950	2350	2900	3500	4375	5350	6800	8150	10350	12250	10400	9050	8050	7100	5500	4300	3800	
20. Pave. Br. No. 4 Luminaire (fL)	.0029	.0038	.0052	.0074	.0109	.0150	.0196	.0326	.0307	.0711	.0738	.0787	.0805	.0852	.0825	.0714	.0720	
21. Longitudinal Distance in MH from No. 5 Luminaire				10.5	10	9.5	9	8.5	8	7.5	7	6.5	6	5.5	5	4.5	4	
22. Pave. Br. Constant/1000 cp (0.5 MH)*				.0047	.0055	.0066	.0074	.0091	.011	.014	.017	.020	.024	.029	.034	.040	.0464	
23. Luminaire cp (0.5 MH)*				1150	1170	1200	1340	1530	1750	2200	2750	3450	4300	5250	6400	7750	9750	
24. Pave. Br. No. 5 Luminaire (fL)				.0054	.0064	.0079	.0089	.0139	.0193	.0308	.0468	.0690	.1075	.1523	.2176	.3100	.4524	
25. Longitudinal Distance in MH from No. 6 Luminaire												10.5	10	9.5	9	8.5	8	
26. Pave. Br. Constant/1000 cp (1.5 MH)*												.00088	.00092	.0010	.0012	.0013	.0015	
27. Luminaire cp (1.5 MH)*												1240	1300	1400	1520	1725	1950	
28. Pave. Br. No. 6 Luminaire (fL)												.0011	.0012	.0014	.0018	.0022	.0029	
29. 0.5 MH Σ PB Combined Σ Pavement Brightness (fL)	.5679	.6505	.6810	.7070	.6996	.6607	.5491	.3933	.3302	.3136	.3289	.3217	.3250	.3396	.3787	.4407	.5679	
FOR TRANSVERSE AVERAGE																		
30. 1.5 MH Σ PB Combined Σ Pavement Brightness (fL) from Row 29 Table I	.3433	.3463	.3628	.3696	.3517	.3392	.3270	.3456	.4208	.4857	.5200	.5354	.5464	.5361	.4770	.3705	.3433	
31. Transverse Average Σ PB Σ Pavement Brightness (fL) 0.5 MH *and* 1.5 MH Row 29 and Row 30 Averaged	.4556	.4984	.5219	.5383	.5257	.5000	.4381	.3695	.3737	.3997	.4245	.4286	.4357	.4379	.4279	.4056	.4556	

Cycle for Longitudinal Average

*Transverse Distance of Roadway Line with respect to Luminaires such as No. 3 shown in Figs. 3 & 4.
**Transverse Distance of Roadway Line with respect to Luminaires such as No. 4 shown in Fig. 5.

0.5 MH Combined Pavement Brightness Longitudinal Average 0.4805
1.5 MH and 0.5 MH Combined Pavement Brightness Longitudinal Average 0.4489
Average minimum alternating lines as shown by Shading Fig. 6 ..... 0.3434

and combined in a manner similar to that previously described for pavement brightness. Table III shows how the constants and luminaires' candlepower are used to compute obstacle brightness for stations at longitudinal distances including 10.5 MH beyond each luminaire.

The 1.5 MH *combined* obstacle brightness ΣOB for several luminaires is the sum of that in each column as shown in Row 17 Table III.

As indicated by the diagonal lines and Row 18 in Table III, the combined 0.5 MH roadway line obstacle brightness from the *diffuse* surface obstacle target is the same as that on the 1.5 MH roadway line except offset 4 MH longitudinally to correspond with luminaire spacing. For example, the combined obstacle brightness ΣOB at longitudinal distance of 1.0 MH beyond luminaire No. 3 on the 0.5 MH line is the same as the obstacle brightness at longitudinal distance of 1.0 MH beyond luminaire No. 2 on the 1.5 MH line.

The 1.5 MH *and* 0.5 MH combined obstacle brightness is the transverse average of the combined obstacle brightness ΣOB shown Row 17 and Row 18 in Table III. As Fig. 6 indicates, using the obstacle brightness at stations 1.0 MH ahead of the pavement brightness stations provides realistic contrast and approximates outdoor test conditions.

The longitudinal average of the combined obstacle brightness shown in Fig. 6 is 0.09 footlambert. This is one-fifth the average pavement brightness although the diffuse reflectance of the surface of the obstacle-target and the pavement is the same, *i.e.* 8 per cent.

Per Cent Loss of Relative Visibility Due to ΣDVB

At each driver-observer viewing position there is an appreciable per cent loss of relative visibility due to *DVB* (disability veiling brightness). As indicated in Fig. 7 the candlepower from several luminaires impinges upon each of a series of positions along the eye-level longitudinal roadway line. Table IV shows the computation of *DVB* from luminaires, such as No. 3, which are at transverse

TABLE III — 1.5 MH.* Also 0.5 MH* Combined Obstacle Brightness Driver-Observer Eye-Path and View Direction.

Row	Luminaire No. 2								Luminaire No. 3								Luminaire No. 4
1. Longitudinal Distance in MH from No. 3 Luminaire	4	3.5	3	2.5	2	1.5	1	.5	0	.5	1	1.5	2	2.5	3	3.5	4
2. Obstacle Brightness Constant/1000 cp (1.5 MH)*									0+	.00679	.01017	.01027	.00913	.00761	.00622	.00509	.00420
3. Luminaire cp (1.5 MH)*									3600	4200	5300	7100	8050	9050	10400	12250	10350
4. Obstacle Brightness No. 3 Luminaire (fL)									0	.02854	.05592	.07294	.07352	.06883	.06469	.06231	.04350
5. Longitudinal Distance in MH from No. 2 Luminaire	0	.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
6. Obstacle Brightness Constant/1000 cp (0.5 MH)**	0	.02448	.02634	.02038	.01480	.01080	.00814	.00630	.00497	.00400	.00331	.00277	.00235	.00201	.00175	.00153	.00135
7. Luminaire cp (0.5 MH)*	3100	3800	5300	7100	8050	8800	9600	10400	9750	7750	6400	5250	4300	3450	2750	2200	1750
8. Obstacle Brightness No. 2 Luminaire (fL)	0	.08811	.14486	.14477	.11917	.09506	.07812	.06545	.04850	.03103	.02119	.01454	.01010	.00693	.00480	.00337	.00236
9. Longitudinal Distance in MH from No. 1 Luminaire	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5			
10. Obstacle Brightness Constant/1000 cp (1.5 MH)*	.00420	.00351	.00295	.00252	.00217	.00188	.00164	.00146	.00129	.00115	.00103	.000935	.000846	.000774			
11. Luminaire cp (1.5 MH)*	10350	8150	6600	5350	4375	3500	2900	2350	1950	1725	1520	1400	1300	1240			
12. Obstacle Brightness No. 1 Luminaire (fL)	.04350	.02858	.01948	.01347	.00951	.00657	.00477	.00342	.00251	.00199	.00157	.00131	.00110	.00096			
13. Longitudinal Distance in MH from No. 0 Luminaire	8	8.5	9	9.5	10	10.5											
14. Obstacle Brightness Constant/1000 cp (0.5 MH)**	.00135	.00120	.00107	.000967	.000871	.000730											
15. Luminaire cp (0.5 MH)**	1750	1530	1340	1200	1170	1150											
16. Obstacle Brightness No. 0 Luminaire (fL)	.00236	.00184	.00144	.00116	.00102	.00084											
17. ΣOB, Combined ΣObstacle Brightness for 1.5 MH* Roadway Line (fL)	.04586	.11853	.16578	.15940	.12934	.10247	.08289	.06887	.05101	.06156	.08661	.08879	.08472	.07672	.06949	.06568	.04586
18. ΣOB, Combined ΣObstacle Brightness for 0.5 MH* Roadway Line (fL)	.05101	.06156	.08661	.08879	.08472	.07672	.06949	.06568	.04586	.11853	.16578	.15940	.12934	.10247	.08289	.06887	.05101
19. Transverse Average ΣOB Combined ΣObstacle Brightness for 1.5 MH *and* 0.5 MH Roadway Lines Column or Distance Average of Numbers Row 17 and Row 18	.04844	.09005	.12619	.12410	.10703	.08960	.07619	.06728	.04844	.09005	.12619	.12410	.10703	.08960	.07619	.16728	.04844

Cycle for Longitudinal Average

*Transverse Distance of Roadway Line with respect to Luminaire such as No. 3, as shown in Fig. 4 and Fig. 3.
**Transverse Distance of Roadway Line with respect to Luminaires such as No. 4 as shown in Fig. 5.

1.5 MH or 0.5 MH Obstacle Brightness Longitudinal Average 0.0911
1.5 MH and 0.5 MH Obstacle Brightness Longitudinal Average 0.0911

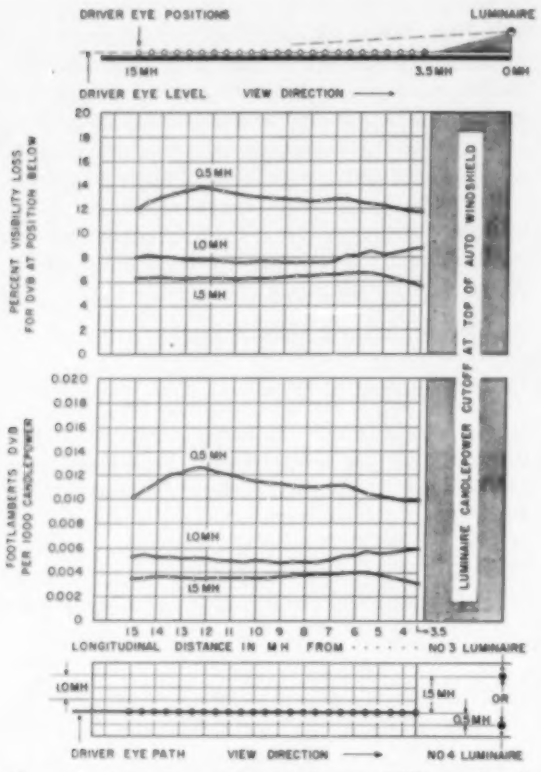


Figure 8. Disability veiling brightness, DVB, produced by 1000 candlepower from a single luminaire, at a series of driver positions along longitudinal eye-level lines at the indicated distances to the driver's left and right, is shown in the lower portion of this diagram. The luminaire is assumed to be cut off from driver view at longitudinal distances of less than 3.5 MH. The per cent loss in relative visibility shown in the upper portion of this diagram is based upon the corresponding DVB for 1000 candlepower. The per cent loss is not directly additive as is shown in Fig. 9.

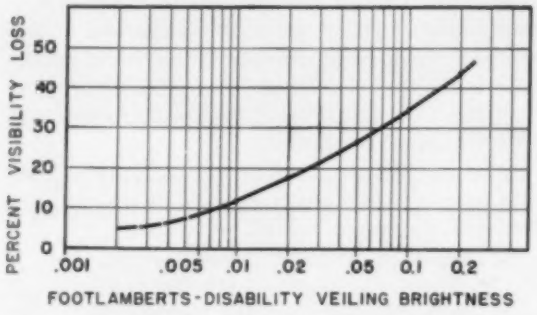


Figure 9. The per cent loss in relative visibility increases, as shown, with increase in disability veiling brightness, DVB, in footlamberts at the driver's eyes. Per cent loss applies only to the relative visibility rating above 1.0 threshold. The per cent visibility loss includes a Reid-Chanon estimate as to the effect of typical fluctuation for drivers traveling 25 to 40 miles per hour.

distance of 1.5 MH to the driver's left. *DVB* constant computations for luminaires, such as No. 4, at 0.5 MH on the driver's right are similar, shown in Table V which will be furnished by the author upon request.

Fig. 8 shows the *DVB* constants from Table IV for successive driver eye-level positions at transverse distance of 1.5 MH, as well as those for luminaires at 0.5 MH and 1.0 MH transverse distance with respect to a single luminaire. The accompanying per cent loss of relative visibility in the upper portion of Fig. 8 is obtained from Fig. 9, based upon Reid-Chanon data.[5] The per cent loss, which does not increase directly with increase in *DVB*, is preferred criteria but not directly additive. The

TABLE IV — DVB, Disability Veiling Brightness Computation of Constants (Column 8) for Driver Positions Along Eye-Level Line 1.5 MH to the Right of Luminaires Such as No. 3 as Shown in Fig. 7.

1 Longitudinal Distance of Driver Position from Luminaire MH	2 D, in MH, Distance from Luminaire LC to Eyes of Driver MH	3 D, in Feet When Luminaire LC 25.7 Feet Above Eye-Level in Feet	4 ϕ Angle in Degrees Between Luminaire LC and Driver Line of Sight Along Eye-Level Line in Degrees	5 Cosine of ϕ = Long. Distance / D	6 Candlepower from Luminaire Toward Eye-Level Position	7 Illumination at Driver's Eyes Normal to Line of Sight Eye-Level $E=\frac{cp}{D}\times\cos\phi$ in Vertical Footcandles	8 DVB Constant per /1000 cp = $\frac{31.4\times\cos\phi\times1000}{\phi D^2}$ or $\frac{31.4\times LC.\ Dist.\times1000}{\phi D^2}$	9 DVB for Driver Position B = $\frac{cp}{1000}\times$ constant from Column 8 in Footlamberts	10 Per Cent Loss in Relative Visibility from Fig. 9
3.5	3.892	116.8	25.9	.89892	9,700	.639	.00308	.02991	21.3
4	4.341	130.2	22.9	.92118	7,500	.407	.00325	.02437	19.6
4.5	4.799	144.0	20.3	.93789	5,100	.230	.00345	.01759	16.3
5	5.255	157.7	18.0	.95106	3,800	.145	.00371	.0141	15.3
5.5	5.729	171.9	16.3	.95980	3,100	.101	.00384	.01190	13.0
6	6.212	186.35	15.0	.96592	2,600	.0723	.00388	.01009	12.0
6.5	6.703	201.1	13.9	.97072	2,000	.0479	.00390	.0078	10.5
7	7.183	215.5	13.1	.97398	1,675	.0352	.00384	.00643	9
7.5	7.685	230.6	12.3	.97704	1,600	.0293	.00381	.0061	8.7
8	8.18243	245.4	11.7	.97922	1,500	.02435	.00373	.005595	8.4
8.5	8.6649	259.9	11.1	.98129	1,400	.0203	.00370	.00518	7.8
9	9.1596	274.8	10.6	.98293	1,300	.0169	.00364	.00473	7.4
9.5	9.669	290.1	10.2	.98419	1,200	.014	.003529	.00423	7
10	10.167	305.0	9.75	.98556	1,100	.0116	.00350	.00385	6.7
10.5	10.64	319.3	9.34	.98676	900	.00871	.00348	.00313	5.6
11	11.17	335.1	8.95	.98782	880	.007741	.00345	.003046	5.15
11.5	11.63	348.9	8.55	.98889	860	.006967	.00349	.003001	5.1
12	12.12	363.6	8.2	.98978	840	.006289	.00350	.00294	4.9
12.5	12.63	378.9	7.87	.99059	820	.005657	.00350	.00287	4.8
13	13.12	393.9	7.55	.99133	800	.005111	.00352	.002816	4.7
13.5	13.61	408.3	7.22	.99208	785	.004672	.00358	.00281	4.65
14	14.11	423.3	7.0	.99255	775	.004293	.00355	.00275	4.55
14.5	14.6	438	6.78	.99300	760	.003934	.00353	.00268	4.5
15	15.1	453	6.58	.99341	750	.003655	.00351	.00263	4.45

TABLE VI — Σ DVB, Combined Disability Veiling Brightness; Also Combined Per Cent Visibility Loss for Driver-Observer Positions in System Along 1.5 MH Eye-Level Line Shown in Fig. 7.

Row	Luminaire No. 2		Luminaire No. 3														Luminaire No. 4
1. Longitudinal Distance in MH from No. 3 Luminaire	4	3.5	3	2.5	2	1.5	1	.5	0	.5	1	1.5	2	2.5	3	3.5	4
2. DVB Constant/1000 cp (1.5 MH)* (Table IV)	.0033	.0031															
3. Luminaire cp (1.5 MH)	7500	9700	← Shielded out by top of Windshield →														
4. DVB No. 3 Luminaire (fL)	.0244	.0299															
5. Longitudinal Distance in MH from No. 4 Luminaire	8	7.5	7	6.5	6	5.5	5	4.5	4	3.5							
6. DVB Constant/1000 cp (0.5 MH)** (Table V)	.0110	.0110	.0111	.0111	.0108	.0104	.0103	.0101	.0099	.0099							
7. Luminaire cp (0.5 MH)	1400	1500	1600	1800	2300	3000	3750	5000	7000	10000	← Shielded out by top of Windshield →						
8. DVB No. 4 Luminaire (fL)	.0154	.0165	.0177	.0199	.0248	.0311	.0386	.0505	.0693	.0990							
9. Longitudinal Distance in MH from No. 5 Luminaire	12	11.5	11	10.5	10	9.5	9	8.5	8	7.5	7	6.5	6	5.5	5	4.5	4
10. DVB Constant/1000 cp (1.5 MH)* (Table IV)	.0035	.0035	.0035	.0035	.0035	.0035	.0036	.0037	.0037	.0038	.0038	.0039	.0039	.0039	.0037	.0035	.0033
11. Luminaire cp (1.5 MH)	840	860	880	900	1100	1200	1300	1400	1500	1600	1675	2000	2600	3100	3800	5100	7500
12. DVB No. 5 Luminaire (fL)	.0029	.0030	.0030	.0031	.0039	.0042	.0047	.0052	.0056	.0061	.0064	.0078	.0101	.0119	.0141	.0176	.0244
13. Longitudinal Distance in MH from No. 6 Luminaire			15	14.5	14	13.5	13	12.5	12	11.5	11	10.5	10	9.5	9	8.5	8
14. DVB Constant/1000 cp (0.5 MH)** (Table V)			.0101	.0108	.0114	.0119	.0122	.0125	.0124	.0121	.0119	.0116	.0114	.0113	.0113	.0111	.0110
15. Luminaire cp (0.5 MH)			625	635	655	690	725	760	795	830	865	900	1000	1100	1200	1300	1400
16. DVB No. 6 Luminaire (fL)			.0063	.0068	.0075	.0082	.0088	.0095	.0099	.0100	.0103	.0104	.0114	.0124	.0136	.0144	.0154
17. Longitudinal Distance in MH from No. 7 Luminaire											15	14.5	14	13.5	13	12.5	12
18. DVB Constant/1000 cp (1.5 MH)* (Table IV)											.0035	.0035	.0036	.0036	.0035	.0035	.0035
19. Luminaire cp (1.5 MH)											750	760	775	785	800	820	840
20. DVB No. 7 Luminaire (fL)											.0026	.0027	.0028	.0028	.0028	.0029	.0029
21. Σ DVB, Combined from System Luminaires at each Driver Position (fL)	.0427	.0494	.0270	.0298	.0362	.0435	.0521	.0652	.0848	.1151	.0193	.0209	.0243	.0271	.0305	.0349	.0427
22. Per Cent Loss in Relative Visibility Due to Combined Σ DVB (fL) at each Driver-Observer Position in System	24.6	26.2	20.1	21.0	23.0	24.7	26.8	29.2	32.6	35.5	17.5	18	19.2	20.2	21.2	22.5	24.6

Cycle for Longitudinal Average

DVB Longitudinal Average ..... .0439
Average Per Cent Loss in Visibility Due to Above Average DVB 23.9

*Traverse Distance of Roadway Line with respect to Luminaires such as No. 3, as shown in Fig. 7.
**Transverse Distance of Roadway Line with respect to Luminaires such as No. 4, as shown in Fig. 7.

eye-level candlepower data are extended out to 15 MH on the driver approach side of each luminaire as shown in Fig. 8 and Table IV. As previously shown,[4] the *DVB* per 1000 candlepower and accompanying per cent relative visibility loss due thereto, as shown in Fig. 8, *does not appreciably decrease with increase in driver distance from the luminaire.* In practice the candlepower from each luminaire is controlled or "cut-off" at high angles toward positions at longitudinal distances of 3.5 MH and beyond. As indicated, the luminaire candlepower is usually cut off from driver view mechanically at distances less than 3.5 MH by the top of auto windshield.[4, 16, 18]

Referring to Table IV, it will be noted that Column 7 shows E in vertical footcandles at driver eye-level and normal to the line of sight. These numbers could be readily combined for a lighting system to provide the combined vertical footcandles. When multiplied by coefficient of reflection, they provide obstacle brightness at eye level, or the height of the upper portion of a pedestrian or vehicle. The formulas in Column 8 are based upon Illuminating Engineering Research Institute recommendation, February 1956:

$$DVB \text{ in footlamberts} = \frac{31.4 \times E}{\theta^2}$$

For *DVB* constant per 1000 candlepower use either

$$\frac{31.4 \times \text{cosine}\,\theta \times 1000}{\theta^2\ D^2}$$

or

$$\frac{31.4 \times \dfrac{\text{longitudinal}}{\text{distance}} \times 1000}{\theta^2\ D^3}$$

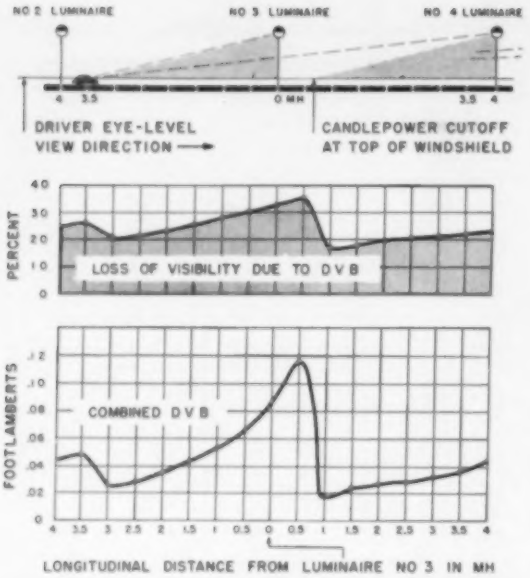


Figure 10. The per cent loss in relative visibility due to the combined disability veiling brightness, ΣDVB, from the lighting system luminaires varies with the driver positon along the roadway due to: control of luminaire candlepower, driver viewing angle, distance from each luminaire and the top-of-auto-windshield cut-off. The longitudinal average ΣDVB is 0.044 and the corresponding average loss in visibility is 24 per cent. The largest loss occurs when the driver-observer is approaching luminaires on his right, such as No. 4, just prior to top-of-auto-windshield cut-off.

Columns 9 and 10 show the "in practice" decrease in *DVB* and reduction of per cent visibility loss respectively due to control or "cut-off"" of the eye-level candlepower from the individual luminaires with increase in driver viewing distance.[4,16]

To compute the *DVB* produced by each luminaire, using the available constants:[16]

$$DVB = \frac{\text{Luminaire Eye-level Candlepower}}{1000} \times DVB \text{ constant}$$

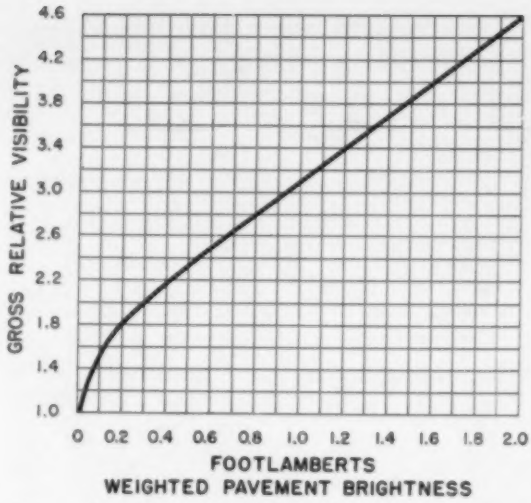
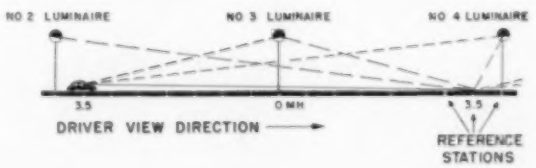


Figure 11. The gross relative visibility varies as shown with weighted pavement brightness. The weighted pavement brightness may consist of pavement brightness and obstacle brightness in typical proportion. In the computation example these factors are weighted 70 and 30 per cent respectively. The relative visibility is as measured in accordance with the scale of the Luckiesh-Moss Low Range Visibility Meter used by Reid-Chanon. The per cent visibility loss due to ΣDVB should be applied to obtain the net relative visibility.

The *DVB* constant is per 1000 candlepower. The combined ΣDVB for each driver eye-level position from the system luminaires is summed up for each column as shown in Table VI. The computation procedure is similar to that explained for Table II. Then the resultant per cent loss in relative visi-



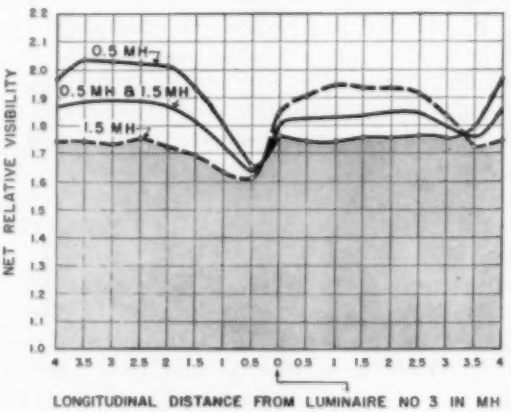


Figure 12. (right). The combined net relative visibility produced along the roadway by the lighting system varies with the longitudinal and transverse location of the pavement brightness stations which the driver is viewing from a distance of 7 MH. The relative visibility is shown for each roadway line 1.5 MH or 0.5 MH. The shading shows that the significant minimum ratings for each longitudinal distance alternates between the 1.5 and 0.5 MH roadway lines. The relative visibility designated 0.5 MH *and* 1.5 MH is computed after obtaining the transverse average of the combined weighted pavement brightness at each longitudinal distance.

bility for the combined ΣDVB at each driver position is obtained from Fig. 9 and inserted in Row 22.

Fig. 10 shows the combined ΣDVB and resultant per cent loss in relative visibility produced by the lighting system luminaires at successive driver positions along the representative eye-level line. The longitudinal average ΣDVB and corresponding average per cent loss of 24 per cent is also shown at the bottom of Table VI.

Computation of Relative Visibility Ratings

The combined net relative visibility correlated with the pavement brightness stations along the 0.5 MH roadway line is obtained from Table VIII. The term "weighted pavement brightness," shown in Row 7, is used instead of "weighted field brightness"[5] to avoid confusion with the important "field brightness" factor in computing relative visual comfort ratings.

Gross relative visibility, Row 8, is derived[5, 16] from a large scale diagram similar to Fig. 11. The per cent loss in relative visibility due to ΣDVB, Row 9, is for driver positions 7 MH ahead of the pavement brightness stations with which gross relative visibility, shown in Row 8, is coordinated. The per cent loss numbers are therefore transposed by 7 MH, as shown in Row 10, for direct correlation with the accompanying visibility stations.

As indicated in Rows 11 and 12, the per cent loss applies only to the relative visibility above 1.0 (bare discernment). The net relative visibility, Row 13, for stations along the 0.5 MH roadway line is plotted in Fig. 12.

The combined relative visibility for the 1.5 MH roadway line, also plotted on Fig. 12, is obtained by similar computation shown in Table VII which will be furnished on request.

In Fig. 12 the shaded area designates the lowest ratings for relative visibility, alternately 1.5 MH then 0.5 MH. These ratings are significant because they show the minimum relative visibility at each distance along the roadway. The longitudinal average of these lowest ratings is 1.72 as shown on the lower portion of Table IX.

The relative visibility for the 1.5 MH *and* 0.5 MH roadway lines plotted in Fig. 12 is computed as shown in Table IX. The transverse average of

TABLE VIII — 0.5 MH* Roadway Line Relative Visibility.

Row		Luminaire No. 2									Luminaire No. 3								Luminaire No. 4
1. Longitudinal Distance in MH from No. 3 Luminaire	5	4.5	4	3.5	3	2.5	2	1.5	1	.5	0	.5	1	1.5	2	2.5	3	3.5	4
2. 0.5 MH* Longitudinal Roadway Line Combined Σ Pavement Brightness. Table II, Row 29			.5679	.6505	.6810	.7070	.6996	.6607	.5491	.3933	.3302	.3136	.3289	.3217	.3250	.3396	.3787	.4407	.5679
3. 0.5 MH* Longitudinal Roadway Line Combined Σ Obstacle Brightness. Table III, Row 18	.0829	.0689	.0510	.0616	.0866	.0888	.0847	.0767	.0695	.0657	.0459	.1185	.1658	.1594	.1293	.1025	.0829	.0689	.0510
4. Obstacle Brightness Row 3 in 1 MH ahead of Pavement Brightness Stations Transposed for Direct Comparison			.0829	.0689	.0510	.0616	.0866	.0888	.0847	.0767	.0695	.0657	.0459	.1185	.1658	.1594	.1293	.1025	.0829
5. 0.7 Combined Σ Pavement Brightness (70% Weighting)			.3975	.4554	.4767	.4949	.4897	.4625	.3844	.2753	.2311	.2195	.2302	.2252	.2275	.2377	.2651	.3085	.3975
6. 0.3 Combined Σ Obstacle Brightness (30% Weighting)			.0249	.0207	.0153	.0185	.0260	.0266	.0254	.0230	.0209	.0197	.0138	.0356	.0497	.0478	.0388	.0308	.0249
7. Weighted Pavement Brightness (0.5 MH)* Row 5 + Row 6			.4224	.4761	.4920	.5134	.5157	.4891	.4098	.2983	.2520	.2392	.2440	.2608	.2772	.2855	.3039	.3393	.4224
8. Gross Relative Visibility Without Σ DVB Loss (0.5 MH)* Fig. 11			2.2	2.3	2.32	2.36	2.38	2.31	2.19	2.0	1.92	1.9	1.91	1.94	1.96	1.98	1.99	2.07	2.2
9. Per Cent Loss in Relative Visibility for Driver Along 1.5 MH Roadway Line Due to Combined Σ DVB. Table VI, Row 22	21.2	22.5	24.6	26.2	20.1	21.0	23.0	24.7	26.8	29.2	32.6	35.5	17.5	18	19.2	20.2	21.2	22.5	24.6
10. Per Cent Loss Row 10 Applies to Relative Visibility at Basic Pavement Brightness Stations 7 MH Viewing Distance Ahead of Driver Position. For Example Transpose Per Cent Loss at 3 MH Approach Side of No. 3 Luminaire to 4 MH Beyond			20.1	21.0	23.0	24.7	26.8	29.2	32.6	35.5	17.5	18	19.2	20.2	21.2	22.5	24.6	26.2	20.1
11. Combined Visibility Rating Above 1.0 Threshold, Bare Discernment. Row 8 Minus 1.0			1.1	1.3	1.32	1.36	1.38	1.31	1.19	1.0	.92	.9	.91	.94	.96	.98	.99	1.07	1.1
12. Row 12 Reduced by DVB Per Cent Loss			.96	1.03	1.02	1.02	1.01	.93	.80	.65	.76	.74	.74	.75	.75	.76	.75	.79	.96
13. 0.5 MH* Net Relative Visibility. Row 13 Plus 1.0			1.96	2.03	2.02	2.02	2.01	1.93	1.80	1.65	1.76	1.74	1.74	1.75	1.75	1.76	1.75	1.79	1.96

Cycle for Longitudinal Average

*Transverse Distance of Roadway Line with respect to Luminaires such as No. 3 shown in Fig. 3.

0.5 MH Relative Visibility Longitudinal Average 1.83

TABLE IX — 0.5 MH* and 1.5 MH* Roadway Lines Transverse Average Relative Visibility.

Row	Luminaire No. 2								Luminaire No. 3								Luminaire No. 4
1. Longitudinal Distance in MH from No. 3 Luminaire	4	3.5	3	2.5	2	1.5	1	.5	0	.5	1	1.5	2	2.5	3	3.5	4
2. 1.5 & 0.5 Transverse Average of Weighted Pavement Brightness. Table VII, Row 7 and Table VIII, Row 7	.3418	.3691	.3799	.4028	.4058	.3872	.3388	.2855	.2858	.3000	.3117	.3271	.3428	.3437	.3316	.3109	.3418
3. Gross Relative Visibility Without DVB Loss. Transverse Average	2.07	2.11	2.14	2.17	2.19	2.15	2.07	1.98	1.98	2.0	2.02	2.04	2.07	2.08	2.05	2.02	2.07
4. Σ DVB Combined for Driver Along 1.5 MH Roadway Line. Table VI, Row 21	.0427	.0494	.0270	.0298	.0362	.0435	.0521	.0652	.0848	.1151	.0193	.0209	.0243	.0271	.0305	.0349	.0427
5. Per Cent Loss in Relative Visibility Due to Combined Σ DVB. Table VI, Row 22	24.6	26.2	20.1	21.0	23.0	24.7	26.8	29.2	32.6	35.5	17.5	18	19.2	20.2	21.2	22.5	24.6
6. Per Cent Loss Row 5 Applies to Relative Visibility at Basic Pavement Brightness Stations 7 MH Viewing Distance Ahead of Driver Position. For Example, Transpose Per Cent Loss at 3 MH Approach Side of No. 3 Luminaire to 4 MH Beyond	20.1	21.0	23.0	24.7	26.8	29.2	32.6	35.5	17.5	18	19.2	20.2	21.2	22.5	24.6	26.2	20.1
7. Combined Visibility Rating Above 1.0, Threshold. Row 3 Minus 1.0	1.07	1.11	1.14	1.17	1.19	1.15	1.07	.98	.98	1.0	1.01	1.04	1.07	1.08	1.05	1.02	1.07
8. Row 7 Less Σ DVB Per Cent Loss	.86	.88	.88	.88	.87	.81	.72	.63	.81	.82	.82	.83	.84	.84	.79	.75	.86
9. 1.5 MH* and 0.5 MH* Transverse Average Net Relative Visibility. Row 8 plus 1.0	1.86	1.88	1.88	1.88	1.87	1.81	1.72	1.63	1.81	1.82	1.82	1.83	1.84	1.84	1.79	1.75	1.86

Cycle for Longitudinal Average

*Transverse Distance of Roadway Line with respect to Luminaires such as No. 3 as shown in Fig. 4.

1.5 MH *and* 0.5 MH Relative Visibility Longitudinal Average 1.81
Average of Minimum Relative Visibility 1.5 MH *or* 0.5 MH as shaded in Fig. 12 1.72

relative visibility ratings for the two pavement brightness stations at each longitudinal distance is obtained by averaging the weighted pavement brightness, from Tables VII and VIII as shown in Row 2. The gross relative visibility ratings above 2.2 may be transversely averaged directly, eliminating Row 2 in Table IX due to the practically straight line relation shown in upper portion of Fig. 11. Net relative visibility, Table IX, Row 9, is plotted in Fig. 12. The longitudinal average 0.5 MH and 1.5 MH relative visibility is used in Fig. 2.

Figs. 13 and 14 show and describe a useful nomograph method of graphically computing the gross and net relative visibility using pavement, obstacle, and DVB brightness data. These illustrations also help visualize the factors involved and method of computation.

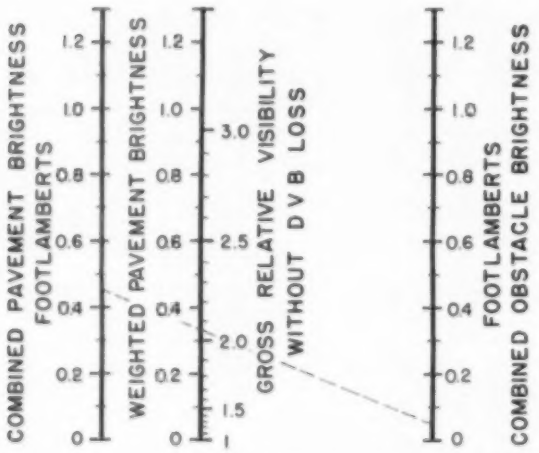

COMBINED PAVEMENT BRIGHTNESS FOOTLAMBERTS
WEIGHTED PAVEMENT BRIGHTNESS
GROSS RELATIVE VISIBILITY WITHOUT DVB LOSS
COMBINED OBSTACLE BRIGHTNESS FOOTLAMBERTS

Figure 13. This nomograph may be used for computation of gross relative visibility. The combined pavement brightness at a station is marked on the scale at the left. The combined obstacle brightness 1.0 MH ahead of the pavement brightness station is marked on the righthand scale. Connect the marks with a straight line to read the weighted pavement brightness and gross relative visibility, without DVB loss. The dash line computation is for pavement brightness station on the 0.5 roadway line at longitudinal distance 4 MH ahead of luminaire No. 3.

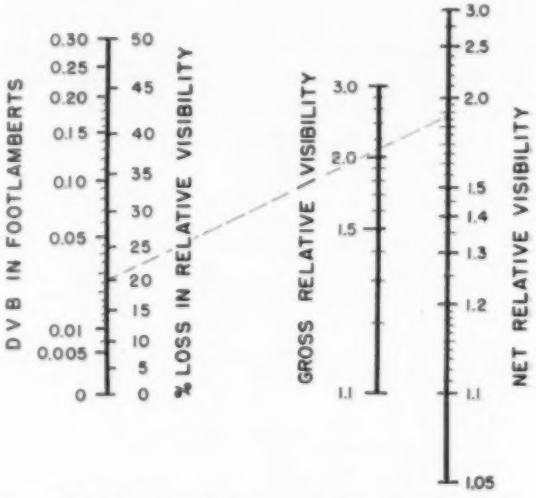


Figure 14. Nomograph for computing net relative visibility. The dash line connects the disability veiling brightness, DVB, and per cent loss on the lefthand scale, with the corresponding gross relative visibility on the midportion scale. Where the projected dash line intersects the righthand scale, read the net relative visibility. The net and gross relative visibility is at pavement brightness station described under Fig. 13. The DVB and per cent loss are for the driver's viewing position 7 MH ahead of the brightness station or at 3 MH on Fig. 10.

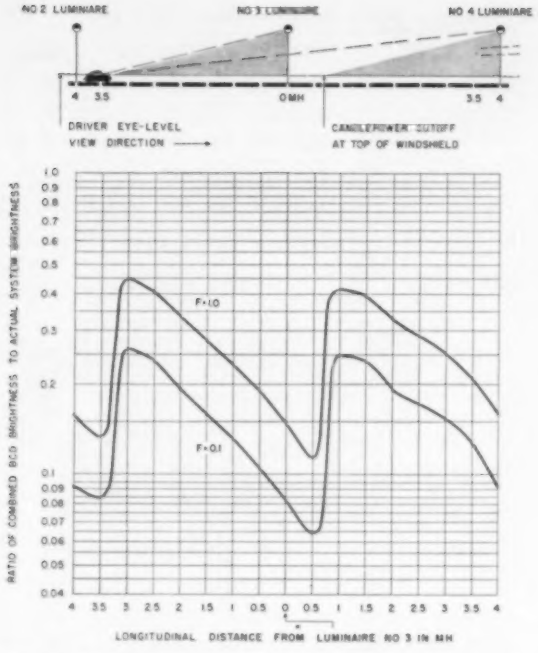


Figure 15. The relative visual comfort ratios vary as shown with motorist position with respect to the luminaires along the roadway. Control of luminaire candlepower along eye-level line and the top-of-auto-windshield cut-off improve the visual comfort rating. The average and minimum rating for field brightness F = 1.0 footlambert are 0.27 and 0.114 respectively. For F = 0.1 footlambert the average and minimum ratings are 0.16 and 0.064 respectively. It is readily apparent that higher average field brightness F also improves visual comfort.

In roadway lighting practice there are instances in which the surfaces of an obstacle, such as an automobile, are specular or have high reflectance. Discernment may then be by glint, reverse silhouette, or surface detail. Such objects provide a safety factor increase in visibility, usually higher than the relative visibility rating.

The method which this paper presents is intended to be practical groundwork for future progress in computation of relative visibility for roadway lighting.

Computation of Relative Visual Comfort Ratings

Computation of the relative visual comfort ratings presented in this paper involves comparison ratios in terms of the combined brightness for a system of luminaires. System ratings in terms of luminaire brightness ratios are most easily interpreted and understood. The brightness of the sev-

TABLE X — Computation of B Actual Brightness of System Luminaires Viewed from Driver Positions Along Eye-Level Line 1.5 MH to the Right of Luminaires Such as No. 3, for Relative Comfort.

1 Longitudinal Driver Distance in MH	2 Eye-Level in Feet	3 Projected Area of Luminaire Source in Square Inches	4 Luminaire Candlepower Eye-Level 1.5 MH	5 Luminaire Source Brightness in Candles per Square Inch	6 Actual B in Footlamberts
3.5	105	130	9700	74.6	33,719
4.0	120	125	7500	60.0	27,120
4.5	135	121	5100	42.1	19,029
5.0	150	118	3800	32.2	14,554
5.5	165	115	3100	26.9	12,159
6.0	180	113	2600	23.0	10,396
6.5	195	111	2000	18.0	8,136
7.0	210	110	1675	17.4	7,865
7.5	225	108	1600	14.8	6,690
8.0	240	107	1500	14.0	6,328
8.5	255	106	1400	13.2	5,966
9.0	270	105	1300	12.4	5,605
9.5	285	104	1200	11.5	5,198
10.0	300	104	1100	10.6	4,791
10.5	315	103	900	8.72	3,941
11.0	330	102	880	8.62	3,896
11.5	345	102	860	8.43	3,810
12.0	360	101	840	8.31	3,756
12.5	375	101	820	8.11	3,666
13.0	390	100	800	8.00	3,616
13.5	405	100	785	7.85	3,548
14.0	420	100	775	7.75	3,503
14.5	435	100	760	7.60	3,435
15.0	450	100	750	7.50	3,390

eral luminaires comprising the foreground of a lighting system as viewed by the automobile driver may be combined[6] for each of a series of driver viewing positions, as indicated in Fig. 7 and shown in Fig. 15.

At each driver position, $\Sigma\overline{B}$, the combined brightness sensation which the driver would experience from the lighting system luminaires if at BCD[17], may be computed. The $\overline{B}$ brightness of each of the system luminaires is that which would produce the BCD sensation, or the visual sensation at the borderline between comfort and discomfort. $\Sigma\overline{B}$ BCD brightness sensation at each driver position may then be compared with ΣB, the *actual* combined brightness of the lighting system luminaires at corresponding driver viewing positions. Thus the relative visual comfort is:

$$\text{Ratio at each position} = \frac{\Sigma\overline{B}, \text{ the combined BCD sensation brightness in footlamberts}}{\Sigma B, \text{ the combined } \textit{actual} \text{ luminaire brightness in footlamberts}}$$

Fig. 15 shows how this ratio of combined brightness varies as the driver proceeds along the roadway. The longitudinal average and the minimum based on a field brightness, F = 1.0 footlambert, were used in the example relative visual comfort ratings in Fig. 2.

The computation of both $\Sigma\overline{B}$, the BCD, and ΣB, the *actual* luminaire brightness is based on luminaires in position along the sides of the roadway, Fig. 7, rather than by conversion to the line of sight. Thus future modifications for improvement of the relative visual comfort ratio of lighting systems may be done by directly decreasing ΣB, or B, the *actual* luminaire source brightness in comparison with $\Sigma\overline{B}$, or B, the BCD brightness com-

TABLE XII — Combined Σ B or Actual Luminaire Brightness. Directly Additive Brightness Method Used for Combined Relative Comfort Rating for Roadway Lighting System — See Lower Portion of Table XV.

Row	Luminaire No. 2							Luminaire No. 3							Luminaire No. 4
1. Longitudinal Distance in MH from No. 3 Luminaire	4	3.5	3	2.5	2	1.5	1	.5	0	.5	1	1.5	2	2.5	3	3.5	4
2. *B*, or BCD Brightness (from Table X)	27120	33719	← Shielded out by top of Windshield →														
3. Longitudinal Distance in MH from No. 5 Luminaire	12	11.5	11	10.5	10	9.5	9	8.5	8	7.5	7	6.5	6	5.5	5	4.5	4
4. *B*, or BCD Brightness (from Table X)	3756	3810	3896	3941	4791	5198	5605	5966	6328	6690	7865	8136	10396	12159	14554	19029	27120
5. Longitudinal Distance in MH from No. 4 Luminaire	8	7.5	7	6.5	6	5.5	5	4.5	4	3.5							
6. *B*, or BCD Brightness (from Table XI)	5921	6283	6554	7322	9176	11900	14374	18666	25312	34804	← Shielded out by top of Windshield →						
7. Longitudinal Distance in MH from No. 7 Luminaire											*15	14.5	14	13.5	13	12.5	12
8. *B*, or BCD Brightness (from Table X)											3390	3435	3508	3548	3616	3866	3756
9. Longitudinal Distance in MH from No. 6 Luminaire			*15	14.5	14	13.5	13	12.5	12	11.5	11	10.5	10	9.5	9	8.5	8
10. *B*, or BCD Brightness (from Table XI)			2825	2870	2961	3119	3277	3399	3557	3875	3828	3950	4339	4791	5153	5580	5921
11. ΣB Combined *Actual* Luminaire Brightness Footlamberts for Each Driver-Observer Position in System (Rows 2+4+6+8+10)	36797	43812	13275	14133	16928	20117	23256	28033	35197	45169	15083	15521	18238	20498	23323	28255	36797

Cycle for Longitudinal Average

Longitudinal Average of Combined *Actual* Brightness 24852

puted for the system luminaires as mounted in position along the roadway.

Actual Luminaire Brightness Factor

The actual brightness, B, of each luminaire as viewed by the driver from each longitudinal position distance is readily computed as shown in Table X. The formula is:

$$B = \frac{\text{Luminaire candlepower toward each position}}{\text{Projected area of luminaire source (sq. in.)}} \times 452 \text{ fL}$$

The constant, 452, converts candles per square inch to footlamberts. Column 3 has been explained under heading "Conditions for Computation Example." Table XI will be furnished on request to the author.

ΣB, the combined *actual* brightness of several luminaires viewed by the driver from each driver eye-level position is shown in Table XII, Row 11. The luminaire brightness is assumed to be directly additive as suggested to the author by the Putnam-Bower paper.[6]

The BCD sensation brightness $\overline{B}$ for luminaire

TABLE XIII — Computation of *B* or BCD Luminaire Source Brightness Data for Driver Positions Along Eye-Level Line 1.5 MH to the Right of Luminaires Such as No. 3 for Relative Comfort When $F = 0.1$, Also $F = 1.0$ Footlamberts Field Brightness.

1 Longitudinal Driver Eye-Level Distance MH	2 D, Actual Distance from Luminaire to Driver's Eyes in Feet	3 Angle of View θ Between Luminaire and Line of Sight in Degrees	4 Projected Area of Luminaire Source in Square Inches	5 ω Visual Size Angle in Steradians Subtended by Luminaire Source $\frac{A \text{ (Sq In)}}{D^2 \text{ (Ft)} \times 144}$ in Steradians	6 *B* Actual Luminaire Brightness from Table X in Footlamberts	7 When $F = 0.1$ Footlambert Field Brightness For BCD = $\overline{B}$ B_c Brightness Source at Eye-Level Along Line of Sight (Putnam-Faucett) Ref (7) in Footlamberts	8 P Position Factor for Source at Angle θ Column 3 and Fig. 16	9 $\overline{B} = P\overline{B}_c$ for Luminaire in Actual Source Position in Footlamberts	10 Ratio $\overline{B}/B$ BCD Brightness to *Actual* Brightness	11 When $F = 1.0$ Footlambert Field Brightness For BCD = $\overline{B}$ B_c Brightness Source at Eye-Level Along Line of Sight (Putnam-Faucett) Ref (7) in Footlamberts	12 P Position Factor Source at Angle θ Column 3 and Fig. 16	13 $\overline{B} = P\overline{B}_c$ for Luminaire in Actual Source Position in Footlamberts	14 Ratio $\overline{B}/B$ BCD Brightness to *Actual* Brightness
3.5	116.8	25.9	130	.0000662	33,719	292	5.39	1,574	.0467	702	2.83	2,128	.06309
4.0	130.2	22.9	125	.0000512	27,120	322	4.44	1,430	.0527	786	2.57	2,020	.0745
4.5	144.0	20.3	121	.0000405	19,029	351	3.70	1,299	.0683	825	2.32	1,914	.1011
5.0	157.7	18.0	110	.0000330	14,554	382	3.06	1,169	.0803	864	2.13	1,840	.1264
5.5	171.9	16.3	115	.0000270	12,159	416	2.56	1,065	.0876	906	1.97	1,785	.1468
6.0	186.35	15.0	113	.0000226	10,396	448	2.34	1,048	.1008	980	1.87	1,795	.1727
6.5	201.1	13.9	111	.0000191	8,136	486	2.16	1,050	.1290	992	1.80	1,786	.2193
7.0	215.5	13.1	110	.0000165	7,865	521	2.02	1,052	.1337	1,035	1.76	1,822	.2315
7.5	230.6	12.3	108	.0000141	6,690	562	1.91	1,073	.1605	1,085	1.71	1,855	.2770
8.0	245.4	11.7	107	.0000123	6,328	600	1.84	1,104	.1745	1,131	1.67	1,889	.2985
8.5	259.9	11.1	106	.0000109	5,966	637	1.77	1,127	.1890	1,177	1.64	1,930	.3236
9.0	274.8	10.6	105	.0000096	5,605	677	1.72	1,164	.2075	1,211	1.61	1,950	.3484
9.5	290.1	10.2	104	.00000853	5,198	721	1.69	1,218	.2342	1,279	1.58	2,021	.3891
10.0	305.0	9.75	104	.00000766	4,791	763	1.64	1,251	.2611	1,327	1.55	2,057	.4292
10.5	319.3	9.34	102	.00000702	3,941	800	1.61	1,288	.3268	1,367	1.53	2,092	.5319
11.0	335.1	8.96	102	.00000631	3,896	844	1.67	1,325	.3401	1,427	1.51	2,155	.5525
11.5	348.9	8.55	102	.00000582	3,810	861	1.53	1,348	.3534	1,472	1.49	2,193	.5747
12.0	363.6	8.2	101	.00000531	3,756	926	1.50	1,389	.3704	1,525	1.47	2,242	.5952
12.5	378.9	7.87	101	.00000489	3,666	968	1.47	1,423	.3876	1,562	1.45	2,265	.6173
13.0	393.9	7.55	100	.00000448	3,616	1,015	1.44	1,462	.4049	1,632	1.43	2,334	.6452
13.5	408.3	7.22	100	.00000417	3,548	1,054	1.42	1,497	.4219	1,680	1.416	2,379	.6711
14.0	422.3	7.0	100	.00000388	3,503	1,089	1.40	1,525	.4348	1,731	1.40	2,423	.6896
14.5	436.0	6.78	100	.00000362	3,435	1,140	1.39	1,573	.4587	1,781	1.39	2,476	.7194
15.0	453.0	6.58	100	.00000338	3,390	1,185	1.36	1,612	.4762	1,834	1.38	2,531	.7463

sources, such as No. 3, viewed from driver positions ranging from 3.5 to 15 MH has been computed in Table XIII. Table XIV for luminaires such as No. 4 will be furnished on request. The formula[6,7] for each of the system luminaires is:

For F, Field brightness = 0.1 footlambert,

$$\overline{B} \text{ or BCD} = P, \text{Position factor} \times \left(\frac{0.43}{\omega 0.62} + 124 \right), \text{fL}$$

For F, Field brightness = 1.0 footlambert,

$$\overline{B} \text{ or BCD} = P, \text{Position factor} \times \left(\frac{0.68}{\omega 0.60} + 531 \right), \text{fL}$$

Three variables are involved:

1. F, Field brightness
2. ω, Size of luminaire source
3. P, Position factor

Field Brightness BCD Factor

The two field brightness conditions, $F = 0.1$ footlambert and $F = 1.0$ footlambert, are those on which data[6,7] are available. The field brightness is the average integrated brightness in the driver's field of view including the brightness of the pavement and objects thereon and near by. Along streets, building front facades and trees are often part of the field brightness. The relative visual comfort is improved by increasing field brightness. It is hoped that, in the near future, integrating, recording instrumentation will be available for measurement of the over-all field brightness for representative roadway lighting systems.[9]

BCD Factor, ω, Size of Luminaire Source

The size of each luminaire source, ω, is the visual solid angle subtended at the driver's eye position by the projected area of the luminaire at the pole bracket location. ω is expressed in steradians as listed in column 5, Table XIII. That portion of the above formula in parentheses is $\overline{B}_L$, or the BCD on the horizontal line of sight computed directly from the Putnam-Faucett[7] studies. This is shown in Columns 7 and 11 of Table XIII.

BCD Luminaire Position Factors

The position factors derived from the recent Putnam-Bower data[6] vary as shown in Fig. 16 for the two field brightness conditions, and for each angle θ, the viewing angle between the driver's horizontal line of sight and the luminaire in position on the pole bracket. Angle θ decreases with increase in the longitudinal distance to the viewing position of the driver, as is shown in Table XIII, Column 3.

The position factors are shown in columns 8 and 12. $\overline{B}$ or the BCD luminaire source brightness is shown in columns 9 and 13.

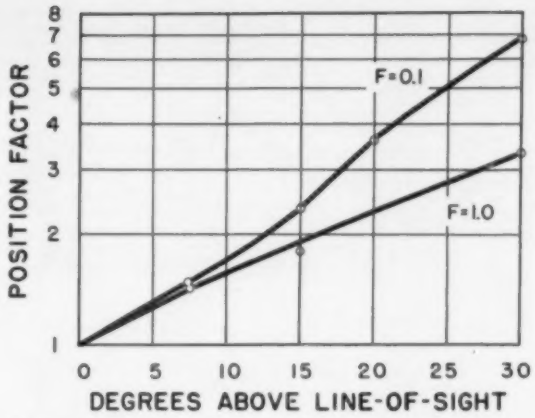


Figure 16. Luminaire position factors, used in computing $\overline{B}$, or the BCD sensation brightness, for the system luminaires, are derived from Putnam-Bower 1957 data, for field brightness $F = 0.1$ footlambert and $F = 1.0$ footlambert. $\overline{B}$, or the BCD brightness, of each luminaire size and viewing angle θ, corresponding to the driver position is computed by multiplying the brightness of a source of the same size which is at BCD on the line of sight by the position factor.

Table XV combines the $\overline{B}$ or BCD brightness of several system luminaire sources by direct additivity. $\Sigma\overline{B}$ in Row 11 shows this summation for the combined BCD at each driver position. This table is based upon field brightness, $F = 1.0$ footlambert. Table XVI for $F = 0.1$ footlambert will be furnished upon request.

For convenience in computing the relative visual comfort ratios, Row 12, in Table XV repeats the ΣB *actual* luminaire brightness at each position from Table XII, Row 11. $\Sigma\overline{B}/\Sigma B$, BCD-to-*actual*, combined luminaire brightness ratios are shown in Row 13 of Table XV and plotted in Fig. 15.

Fluctuation in Brightness and Relative Visual Comfort

The fluctuation in combined $\Sigma\overline{B}$, BCD, and ΣB, *actual*, luminaire brightness, also the relative visual comfort ratios, is shown by the numbers in the lower portion of Table XV. Fig. 15 makes the fluctuation in ratio readily apparent, for each driver position. The longitudinal distances between the low relative visual comfort ratios may be readily converted to time interval based on an assumed vehicle speed,[4] *i.e.* 2-second intervals at approximately 40 miles per hour. The dynamic effect of fluctuations on the driver is one of the most important of many factors on which increased data[1] are highly essential.

TABLE XV — Combined $\bar{B}$ or BCD System Luminaire Brightness. 1.0 Footlambert Field Brightness. For Relative Comfort Rating of Roadway Lighting System, See Row 13 Below.

Row	Luminaire No. 2				Luminaire No. 3												Luminaire No. 4
1. Longitudinal Distance in MH from No. 3 Luminaire	4	3.5	3	2.5	2	1.5	1	.5	0	.5	1	1.5	2	2.5	3	3.5	4
2. $\bar{B}$, BCD Brightness (Table XIII, Column 13)	2020	2128	⟵ Shielded out by top of Windshield ⟶														
3. Longitudinal Distance in MH from No. 5 Luminaire	12	11.5	11	10.5	10	9.5	9	8.5	8	7.5	7	6.5	6	5.5	5	4.5	4
4. $\bar{B}$, BCD Brightness (Table XIII, Column 13)	2242	2193	2155	2092	2057	2021	1950	1930	1849	1855	1822	1786	1795	1785	1840	1914	2020
5. Longitudinal Distance in MH from No. 4 Luminaire	8	7.5	7	6.5	6	5.5	5	4.5	4	2.5							
6. $\bar{B}$, BCD Brightness (Table XIV, Column 13)	1569	1524	1491	1465	1445	1441	1414	1490	1403	1448	⟵ Shielded out by top of Windshield ⟶						
7. Longitudinal Distance in MH from No. 7 Luminaire											15	14.5	14	13.5	13	12.5	12
8. $\bar{B}$, BCD Brightness (Table XIII, Column 13)											2531	2476	2423	2379	2334	2265	2242
9. Longitudinal Distance in MH from No. 6 Luminaire			15	14.5	14	13.5	13	12.5	12	11.5	11	10.5	10	9.5	9	8.5	8
10. $\bar{B}$, BCD Brightness (Table XIV, Column 13)			2224	2188	2156	2058	2007	1956	1919	1840	1818	1789	1707	1683	1637	1611	1569
11. $\Sigma\bar{B}$ Combined System Luminaire BCD Brightness at Each Driver-Observer Position Footlamberts (Rows 2+4+6+8+10)	5621	5945	5670	5465	5458	5920	5271	5296	5211	5143	6171	6031	5925	5847	5831	5790	5831
12. ΣB from Table XII, Row 11, Combined *Actual* Brightness of System Luminaires	36797	43812	13275	14133	16928	20117	23256	28033	35197	45169	13083	15521	18238	20498	23323	28255	36797
13. Relative Comfort Rating Ratio $\Sigma\bar{B}/\Sigma B$ (Row 11/Row 12) $F = 1.0$ Footlambert	0.1565	0.1333	0.4425	0.4016	0.3344	0.2747	0.2309	0.1690	0.1481	0.1139	0.4098	0.3681	0.3247	0.2849	0.2509	0.2049	0.1585
			⟵ Cycle for Longitudinal Average ⟶														

Relative Comfort Rating — Longitudinal Average of $\Sigma\bar{B}/\Sigma B$ Ratio 0.2681
Minimum Relative Comfort Rating is 0.1139 at 0.5 MH Driver Position in System.
$\Sigma\bar{B}$ Longitudinal Average of System BCD Brightness as Shown in Row 11 ..... 5688 Footlamberts.

Correlation with Outdoor Relative Visual Comfort Ratings

The computed minimum combined system visual comfort rating of 0.11, Fig. 2 and Fig. 15, seems reasonable in comparison with an outdoor, full-scale test minimum rating of 0.19 for a system of luminaires which would be expected to have a higher relative visual comfort rating because of lower eye-level candlepower distribution from the luminaires. The outdoor 0.19 rating is based upon four modern luminaires equipped with 15,000-lumen filament lamps and spaced 100 feet staggered. By comparison, we estimated 25,000-lumen lamp size for the hypothetical luminaire[4] candlepower distribution used for computation in this paper.

The outdoor, full-scale rating of 0.19 is based upon a geometric mean of 480 observations, 48 relative visual comfort ratios by 21 observers using the Guth Evaluator[12] on a street at Hendersonville,[29] N. C. The observer position with respect to luminaires was that which was expected to show a minimum visual comfort rating. The comparison source of the Guth Evaluator is viewed with adjacent concrete pavement brightness ranging to 0.92 footlamberts.

Other Summation Methods Tried and Discarded

Tables were prepared, but have been discarded, which summed up brightness ratios, $B/\bar{B}$, for each luminaire at each driver position. For $F = 1.0$ footlambert this method showed $\Sigma(B/\bar{B})$ maximum discomfort ratio to be 29.63. The reciprocal $\Sigma(\bar{B}/B)$ which might be considered minimum relative visual comfort is 0.034. The same procedure for field brightness, $F = 0.1$ footlambert, gives maximum discomfort ratio $\Sigma(B/\bar{B})$ of 57.0 and reciprocal minimum relative visual comfort of 0.0175.

Using summation of size ratios $\Sigma\omega/\bar{\omega}$ or $\Sigma\bar{\omega}/\omega$ produced rating results which are even less reasonable.

Compile Ratings for Other Representative Roadway Lighting Layouts

Relative visual comfort and relative visibility ratings should be computed and compiled for representative layouts of roadway lines, and driver-observer eye position lines with typical luminaire

sizes and candlepower distributions. Then, by interpolation, ratings may be estimated for lighting systems being considered for installation. Fig. 17 shows example layouts that may be advantageously computed. The top layout shows one-side luminaire spacing as is typical for portions of the Interstate Defense Highway System.

The spacing of any layout may be varied as desired. If the spacing is in multiples of 0.5 MH, the foregoing data, constants, and method are most easily applied, *i.e.* spacings of 90, 105, 120, 150, 195 feet, etc.

Summary

Relative comfort and relative visibility ratings can and should be computed for better appreciation of roadway lighting effectiveness and more general understanding thereof by the roadway user. Development work and analysis of available data have significantly improved the effectiveness of roadway lighting during the past 20 years. Further use of data, and much more data, are essential to accelerate future progress in night motor vehicle transportation.

Greater attention to the technological details by which seeing is improved is of interest to public officials and engineers. Seeing factor ratings will help establish the traffic benefits derived in night driving under *good* roadway lighting.

The active interest of many people is developing. It is hoped that this paper, and the method and data which it makes available, will encourage others to aid the improvement of roadway lighting for night comfort, visibility, and safe, convenient traffic movement. Better night motor vehicle transportation is an objective which warrants the combined use of the best research data and engineering scientific skills.

Acknowledgments

The author gratefully acknowledges the counsel and assistance of his associates. In particular, appreciation is extended to the IES Subcommittee on Roadway Lighting Principles. This Subcommittee is comprised of P. B. Clark, W. H. Dorman, W. H. Edman, M. E. Keck, W. B. Elmer, F. E. Moesta, G. A. Nagel, H. F. Wall, J. W. Young; Charlex Rex, Chairman. Members ex officio: D. W. Rowten, T. J. Seburn, and L. F. Heckmann. Also very special thanks to Dr. Sylvester K. Guth, Prof. Russell E. Putnam, and the IERI Technical Advisory Committee on Light and Vision for their aid and encouragement during the past several years.

Appreciation also to R. E. Faucett for counsel in comfort calculations. To L. R. Herman for nomo-

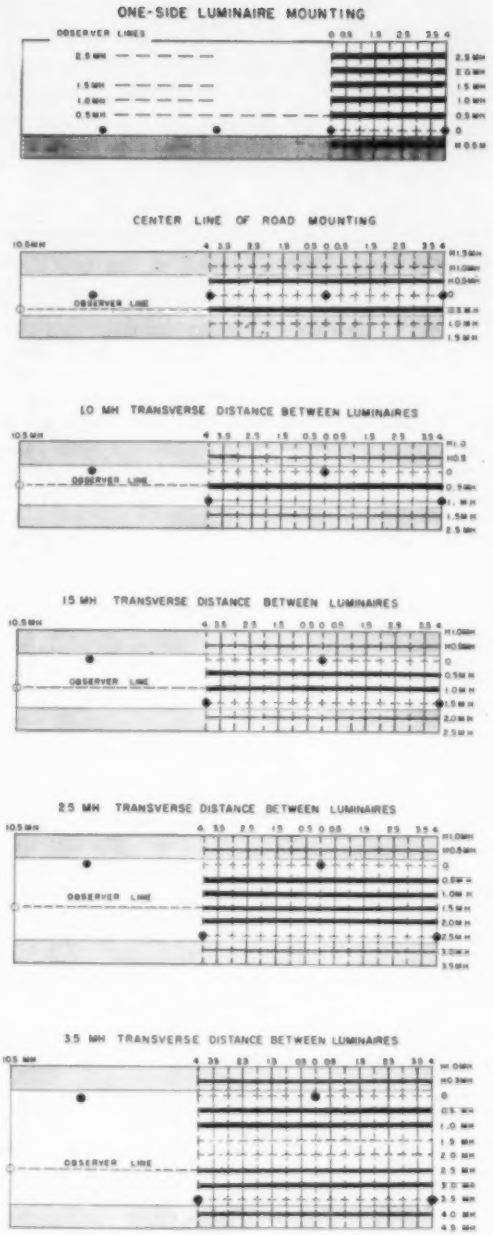


Figure 17. Relative visual comfort and relative visibility ratings should be computed and compiled for representative layouts of roadway lines and driver-observer eye position lines involving typical luminaire sizes and candlepower distributions. Then, by interpolation, ratings may be estimated for lighting systems being considered for installation. The top layout shows one-side luminaire spacing as is typical for portions of the Interstate Defense Highway System.

graphs for calculations of gross and net relative visibility as presented in Fig. 13 and Fig. 14. Calculations by J. S. Franklin, Miss R. G. Hallows, and Mrs. F. W. Thompson of constants for conversion of candlepower at stations along longitudinal roadway lines to horizontal footcandles; for obstacle brightness; for angle θ at eye-level positions; lateral and vertical angles; and candlepower estimates from the hypothetical isocandle diagram along eye-level line positions and pavement stations along longitudinal roadway lines. Also to A. B. Gough, Mrs. Thompson, and Mr. Herman for statistical analysis of Guth Evaluator data and for aid in computations of relative comfort ratings by various methods, resulting in the adoption of the method used in this paper.

References

1. Armed Forces–NRC Committee on Vision: "The Visual Factors in Automobile Driving," Report, Conclusion and Plans for Future Action. Publication 574 of National Academy of Sciences–National Research Council.

2. Rex, Charles H.: "Principles and Figures of Merit for Roadway Lighting as an Aid to Night Motor Vehicle Transportation," Highway Research Board Night Visibility Committee 1956, Publication 438.

3. Rex, Charles H.: "Improving Seeing Efficiency with Roadway Lighting," *Traffic Engineering*, August 1956.

4. Rex, Charles H.: "Luminaire Light Distribution Principles," ILLUMINATING ENGINEERING, Vol. L, No. 12 (December 1955).

5. Reid, Kirk M., and Chanon, H. J.: "Evaluation of Street Lighting," *Transactions of the Illuminating Engineering Society*, Vol. XXXIV, page 1209 (1939).

6. Putnam, R. C., and Bower, K. D.: "Discomfort Glare at Low Adaptation Levels — Part III, Multiple Sources," ILLUMINATING ENGINEERING, Vol. LIII, No. 4 (April 1958).

7. Putnam, R. C., and Faucett, R. E.: "The Threshold of Discomfort Glare at Low Adaptation Levels," ILLUMINATING ENGINEERING, Vol. XLVI, No. 10 (October 1951).

8. Fry, Glenn A.: "The Evaluation of Discomfort Glare," ILLUMINATING ENGINEERING, Vol. LI, No. 11 (November 1956).

9. Fry, Glenn A.: "Disability Brightness Meter Which Will Integrate and Record Total Brightness Viewed by Driver," presented at Vision Research Symposium, IERI Annual Report, Dearborn, Mich., March 3, 1958. Also "The Use of the Luckiesh-Moss Visibility Meter for Prescribing Illumination," ILLUMINATING ENGINEERING, Vol. XLVII, No. 7 (July 1952).

10. Finch, D. M., and Palmer, J. D.: "Assessment of Nighttime Roadway Visibility," Highway Research Board Bulletin 163, National Academy of Sciences–National Research Council, Publication 523.

Finch, D. M., and Simmons, A. E.: "Instrument for the Evaluation of Night Visibility on Highways," ILLUMINATING ENGINEERING, Vol. XLVIII, No. 10 (October 1953).

Finch, D. M.: "Some Factors Influencing the Visibility of Roadway Obstacles," ILLUMINATING ENGINEERING, Vol. LII, No. 3 (March 1957).

11. Blackwell, H. R.: "Visual Task Evaluator," report presented at the Vision Research Symposium, Dearborn, Mich., March 3-4, 1958, Annual Report IERI. IES National Technical Conference Paper, 1958. Notes and correspondence.

12. Guth, S. K.: "Discomfort Glare Evaluator," report presented at the Vision Research Symposium, Dearborn, Mich., March 4, 1958. IES National Technical Conference Paper, 1958.

13. Ruff, H. R., and Lambert, G. K.: "Relative Importance of the Variables Controlling Street Lighting Performance," RLP. 334, Research Laboratories, BTH Co., Ltd., Rugby, England. Attention is suggested to the references used in this paper.

14. Hopkinson, R. G.: "Discomfort Glare in Lighted Streets," *Transactions of the Illuminating Engineering Society* (London), Vol. V, No. 1 (January 1940).

Hopkinson, R. G.: "Evaluation of Glare," ILLUMINATING ENGINEERING, Vol. LII, No. 6 (June 1957).

15. Harris, A. J.: "Visibility on the Road," *Transactions of the Illuminating Engineering Society* (London), Vol. 22, No. 9 (1957).

16. Rex, Charles H.: Unpublished data and reports on behalf of the Subcommittee on Roadway Lighting Principles to the IES Roadway Lighting Committee and IES Technical Committee Forums. Extensive data and instructions for use provided to and being used by the Subcommittee members and others.

17. Guth, S. K.: "Comfort in Lighting," ILLUMINATING ENGINEERING, Vol. LI, No. 2 (February 1956).

Guth, S. K.: "Quality of Lighting," ILLUMINATING ENGINEERING, Vol. L, No. 6 (June 1955).

18. Stonex, K. A., Assistant Director, General Motors Proving Ground: "1958 average driver eye height 49.8 inches and top of auto windshield cut-off is at vertical angle 77 degrees." For 1955 autos the cut-off was 76 degrees.[4] There is little practical difference. 1955 data may represent average auto on road.

19. Rex, Charles H.: "Technical and Practical Aspects of Highway Lighting," *Proceedings of the Institute of Traffic Engineers*, Vol. 8, p. 41 (1937).

20. McPhail, Robert G.: "Analysis of Light Distributions from Linear Source Street Luminaires," ILLUMINATING ENGINEERING, Vol. LIII, No. 4 (April 1958); and discussion thereof.

21. Section on Street and Highway Lighting, *Traffic Engineering Handbook*, Institute of Traffic Engineers, 1941 and 1950.

22. Rex, Charles H.: "Roadway Lighting for Efficiency," a paper presented at the Annual Meeting of the Institute of Traffic Engineers, September 11, 1952, Chicago, Ill.

23. Rex, Charles H.: "Report on the American Standard Practice for Street and Highway Lighting," a paper presented at the IES National Technical Conference, September 1952, Chicago, Ill.; information with regard to roadway lines, distance and light distributions.

24. American Standard Practice for Street and Highway Lighting, published by the Illuminating Engineering Society. Approved February 27, 1953, by the American Standards Association.

25. Nagel, George A.: "A Highway Lighting Test Installation," ILLUMINATING ENGINEERING, Vol. LII, No. 3 (March 1957).

26. Franklin, J. S.: "Good Street Lighting Equals Visibility Plus Comfort," *G-E Review* (March 1956).

27. Franklin, J. S.: "Automated Universal Distribution Photometer," ILLUMINATING ENGINEERING, Vol. LIII, No. 12 (December 1958).

28. Reid, K. M., and Toenjes, D. A.: "Appraisal of Discomfort Glare on Lighted Streets," ILLUMINATING ENGINEERING, Vol. XLVII, No. 3 (March 1952).

29. Swetland, R. M., and Tobin, K. D.: "Demonstration Laboratory for Outdoor Roadway Lighting," ILLUMINATING ENGINEERING, Vol. LIV, No. 5 (May 1959).

DISCUSSION

R. E. BALLARD:* Mr. Rex's paper on this vastly complicated subject is a milestone of progress. The use of footcandles as a measure of quality of illumination has long been recognized as a ridiculously outmoded crutch. Roadway lighting is intended to produce comfortable optimum visibility and there is not necessarily any relationship between footcandles and visibility as such.

The obvious improvement of standard techniques which were used in developing the basic data of this paper indicates a marked advance in the difficult problem of evaluating visibility.

Mr. Rex's paper deals primarily with fixed brightness sources. It would be interesting to know the effect on Relative Visibility when moving brightness sources are used in conjunction with the usual fixed brightness sources.

The assimilation of the data in this paper certainly brings the time nearer when we can break through the "footcandle barrier" to an accurate intelligent evaluation of visibility.

T. W. FORBES:** This paper is of much interest and importance in that it shows how factor ratings may be derived not only for the various factors in relative visibility but also for the comfort factors relating to glare. Veiling brightness has been widely recognized as of great impor-

*Connecticut Light and Power Co., Hartford, Conn.
**Assistant Director for Research, Highway Traffic Safety Center, Michigan State University, East Lansing, Mich.

tance because of its interference with visibility. The factor of discomfort has also been measured, as pointed out by Mr. Rex, but perhaps has not been thought of quite as much importance.

From the human factor and safety points of view, the comfort factor may be of as much importance as visibility. Reduced visibility from veiling glare, from spotty pavement brightness and all the other factors which have been so carefully analyzed are of primary importance, but visual factors leading to fatigue are also of major importance in the seeing task. Drowsiness may be induced by factors causing visual fatigue or, if present from previous lack of sleep, discomfort glare may enhance drowsiness and result in complete eye closure.[1]

The paper suggests a method by which these various factors may be put together, including this highly important comfort factor, to produce a relative rating for roadway lighting. Whether all will agree that this procedure is the best which can be developed I do not know, not being an expert in each of these specialties. But whether or not other and better methods of deriving such a rating are developed, the importance of such an undertaking seems evident. Mr. Rex is to be congratulated on demonstrating a procedure by which this may be done, thus laying the groundwork for further development.

Also, it may be that with the increasing availability of electronic computers further developments along the line suggested will furnish a set of badly needed data for the mathematical simulation both of vehicle operation and separately of traffic flow under night driving conditions. Such simulation is being developed and when achieved will represent a scientific breakthrough which will facilitate highway and safety research of all sorts. For accurate simulation of night driving conditions as well as for valid rating of roadway lighting, combination of the different visibility and visual comfort factors into ratings of a mathematical type will be basic.

1. For experimental study of drowsiness behind the wheel, see Forbes, T. W., Katz, M. S., Cullen, J. W., and Deterline, W. A.: "Sleep Deprivation Effects on Components of Driving Behavior," Highway Research Abstr. 1958, 28, No. 1, pp. 21-26.

SYLVESTER K. GUTH:* One of the real problems continually facing us is how to apply fundamental laboratory data to practical lighting situations. This has been emphasized in several of the research papers presented at the 1958 National Technical Conference. It usually takes someone who has the courage of his convictions to get things started. Mr. Rex has done this and I should like to give him a big "E" for effort.

Many of us probably could find cause to disagree with him on certain details of his method for computing visibility and comfort factors. Inevitably, some assumptions are involved. However, using the available data together with a judicial mixture of practical experience and logical judgment, Mr. Rex has devised a procedure for determining visual rating factors for roadway lighting. The absolute numerical ratings are not too important. The real question is whether the ratings represent the relative order of visibility and discomfort obtained with various roadway lighting systems. It appears that this is the case but, of course, the final proof will be to compare the computations with actual observations made with specific lighting systems.

In a way, Mr. Rex is attempting to do the same thing that Ward Harrison did when he first proposed his glare rating method for interior lighting. Later, with Phelps Meaker, the details of the computations were worked out. As more information became available, the procedure was modified and it now has been used for some years with considerable success.

Mr. Rex is well on his way through the first stages of the work and I hope he will continue his activities in this area. Furthermore, others, especially those interested in research, should become familiar with it and perhaps be stimulated to help close the informational gaps.

G. K. HARDACRE:* We are aware today of the problem confronting us concerning the need for the promotion of safety for the automobile driver on our congested streets and highways. Our automobile traffic rate has reached the point where one-way traffic on business streets and parking restrictions on arterial streets are necessary. Present volume of automobile traffic has also required cross-country expressways. To further the congestion hazards, increased driving speed is a matter of necessity.

The IES Roadway Committee has maintained a continuous study of street lighting requirements, to which Mr. Rex has long been a very able contributor. A generalized recommended practice has been established and maintained for some time by this committee. However, I believe that to cope with today's traffic problem we need an expansion of the fundamentals which Mr. Rex has accomplished in his new paper.

He has made a timely contribution to the street lighting practice with the development of seeing and visibility ratings in his usual thorough manner. The established data which will be evolved from this study should be of great value to the design engineer in planning the required lighting for traffic problems involved.

R. G. HOPKINSON:** I have followed Mr. Rex's work with great interest, because he is careful to take into account factors which I believe to be of importance in street lighting. In England, the main stress in street lighting has been on visibility first and foremost, and this is wise, but in practice we have somewhat neglected the effects of glare and visual discomfort, which is not wise. Our researches in these matters have been pursued with vigor, as you know, but it has been left to others, especially the Dutch, to be more assiduous in applying the results of our research work to actual street lighting practice. I am sure that Mr. Rex is wise in good time to stress the importance of visual comfort and freedom from glare in any over-all appraisement of street lighting.

In his tackling of the problem of disability glare, he follows the well-worn path of the researchers who have spent most of their time on the effects of veiling brightness. This is undoubtedly the most important effect of disabling glare, but the diminution of perceptible contrast is not the only effect. Schouten showed, as long ago as 1938, that the disabling effects of glare were at least twofold. One effect is the long-period veiling effect, which has been studied by Holladay, Stiles, Fry and others. The other is a very short-period effect, which Schouten considered to be of electrical origin in retina, and which causes a temporary diminution in the apparent brightness of a scene for a matter of tenths of a second at most. In a

*Radiant Energy Effects Laboratory, Lamp Division, General Electric Co., Cleveland, Ohio.

*Public Service Co. Southern Division, Commonwealth Edison Co., Joliet, Ill.
**D.S.I.R., Building Research Station, Garston, Herts, England.

lighted street, this momentary loss of vision may be significant as a bright street lamp or car headlamp comes instantaneously into the field of view when one is driving at very high speeds. In such circumstances, tenths of a second may mean yards between safety and disaster. I would therefore advocate more detailed research into this short-period glare phenomenon with specific reference to street lighting visibility.

G. A. NAGEL:* It is always an honor and privilege to discuss a paper by Mr. Rex. He has consistently promoted "comfortable" night driving, knowing full well that comfortable night driving will bring with it safety, which we all so much desire.

In his paper, Mr. Rex proposes a method by which seeing benefit ratings may be computed in terms of relative comfort and relative visibility. He offers for general use a method and data for computing such ratings, and he includes therein such factors as pavement brightness, obstacle brightness and disability veiling brightness — the three "bugaboos" which we have tried so hard in the past to correlate.

There is no doubt that accepted simplified ratings will help the design engineers to provide a system which will give optimum over-all efficiency and result to the benefit of the roadway user. It is truly hoped that the time will come when we can have "figures of merit" by which a lighting installation can be judged.

We should all thank Charles Rex for the time and effort this paper represents, and we should enlarge upon it so that comprehension of objectives will be improved, complexity reduced and standardization possibilities revealed.

RUSSELL C. PUTNAM:** In the researches on Discomfort Glare at Low Adaptation Factors which have been carried on the last few years at Case Institute of Technology[1,2,3] our purpose was to establish fundamental data regarding visual sensation at the borderline between comfort and discomfort for conditions involving background brightness, visual size of light sources, position factors, the relationship of the effect of multiple light sources, etc., in regions that are applicable to street and highway lighting. It has been our hope that these data might be used as a basis for a practicable system of evaluating the comfort or discomfort of a proposed street or highway lighting installation, much as the visual comfort index (VCI) tables function in the case of interior lighting. We are, therefore, very much pleased that Mr. Rex has incorporated some of our findings with other researches in this paper dealing with the complex problems pertaining to highway lighting.

Our investigations were based on uniform background brightnesses of 1.0, 0.1, 0.01, 0.001 footlamberts. The author seems to key most of his computations to field brightnesses of 1.0, 0.1, 0.01, 0.001 footlambert. The Are not the field brightnesses of 0.01 and 0.001 footlambert important also, especially in highway lighting?

We think that Mr. Rex is to be congratulated for his paper, and the large amount of pioneering work that was necessary.

1. Putnam, R. C., and Faucett, R. E.: "The Threshold of Discomfort Glare at Low Adaptation Levels," ILLUMINATING ENGINEERING, Vol. XLVI, No. 10 (October 1951).

2. Putnam, R. C., and Gillmore, W. F., Jr.: "Discomfort Glare at Low Adaptation Levels II—Off Axis Sources," ILLUMINATING ENGINEERING, Vol. LII, No. 4 (April 1957).

3. Putnam, R. C., and Bower, K. D.: "Discomfort Glare at Low Adaptation Levels Part III—Multiple Sources," ILLUMINATING ENGINEERING, Vol. LIII, No. 4 (April 1958).

DOMINA EBERLE SPENCER:* The aim of Mr. Rex to develop a quantitative method of evaluating roadway lighting is entirely laudable. However, the same eyes are seeing roadways and working in schools, offices, factories and kitchens. Any method developed for roadways should apply to all levels from sunlight to starlight. It should be based on sound visual data and be applicable to all visual fields.

At the present time I do not feel that the BCD method is sufficiently well established to be acceptable as a standard method of evaluation. For example, the "field brightness" is still not defined without ambiguity; the effect of motion of the driver is not considered at all in the experiments on which BCD calculations are based. Probably a moving glare source in the periphery is much more annoying than a stationary one. How do textured or patterned luminaires compare with uniform ones? The BCD procedure is more nearly ready for use at low levels with small sources than at very high levels with very small sources, but this does not mean that it is free from ambiguity even for roadway lighting.

Likewise there are reservations in the specification of supra-threshold levels of visibility. Exactly what is the variable density filter doing to the task? Both absorption and diffusion are present. Exactly what is their effect on vision? What is the state of adaptation? How is the effect of glare sources in the surround to be treated when the visibility meter is used? What is the effect of motion on the settings of the visibility meter?

The system suggested by Mr. Rex is unpleasantly complicated and is based on two procedures which are still somewhat questionable.

A simpler way of evaluating the roadway lighting would be to employ the delos method.[1] The procedure is based directly on extensive experimental data. Theoretical calculations are readily carried out and experimental evaluation is possible if a photo-electric helios (brightness) meter with a shield to convert it into an adaptation helios meter is developed. Optimum lighting has a delos of 1. Current interior lighting may have a delos as high as 80 per cent or even 90 per cent. Street lighting would have a delos of the order of 20 per cent if direct glare were eliminated. Non-uniformity of the surround would reduce this value to 1 per cent or below in some cases.

1. Moon and Spencer, *Lighting Design*, Addison-Wesley Press, Cambridge, Mass., 1948, Chap. VIII.

GILBERT A. TROSPER:** I take pleasure in submitting a discussion on Mr. Rex's paper. I feel he is making a worthwhile effort to brush away the translucent screen of uncertainty in the complex problems of seeing on our streets and roadways. It is difficult to get agreement among experts in this field.

However, general agreement has been reached on the need for more research, and Mr. Rex is to be commended for his contribution to that complex problem. The principles involved in his paper appear to have great possibilities. Ratings such as he proposes would be of much help in the field in determining the effectiveness of roadway lighting.

*Consulting Engineer, Chester, Conn.
**Case Institute of Technology, Cleveland, Ohio.

*University of Connecticut, Storrs, Conn.
**Chief Street Lighting Engineer, Pacific Gas and Electric Co., San Francisco, Calif.

I would like to submit here a suggestion which may be of assistance in presenting his ideas. It consists of showing the same values in graph form. It appears to me that the two ratings — visibility and comfort — can be shown as bands of approved values of each across a chart from left to right. Perhaps the space between reasonable limits could be colored and would represent the tolerance that must be allowed as a satisfactory band of lighting of a "comfortable visual" field. The distance from the left hand side of the sheet to the other could be shown as the distance between lights.

This rating method could be applied quickly to any installation, existing or projected, without much data at hand.

ROBERT R. WYLIE:* As is to be expected, Mr. Rex has given us another signpost along the way to better roadway lighting. The patient development of this detailed study attests to the stature of true engineering development which Mr. Rex typifies.

There has been considerable discussion of BCD, VCI or figures of merit. There still remains a real possibility that inherently there may be aberrations in these techniques which might cause results not in agreement with practice. Sometimes roadway signs can be misleading — which way do we go?

I sincerely hope that Mr. Rex will agree that rigid, inflexible field specifications by specifying agencies, who wish to base their evaluations on the techniques developed in this paper, are not within the intent of the author.

CHARLES H. REX:** Such generous discussion is deeply appreciated by the many people who have contributed to the work which this paper presents. It is encouraging to have such widespread interest in the objectives and accomplishment thus far. The work will be continued with confidence. Extensive support is evident.

Mr. Ballard's interest in the effect of moving brightness sources used in conjunction with the usual fixed brightness sources is typical of the extent of future studies.

Dr. Forbes' statement that "the comfort factor may be of as great importance as visibility" gives us an estimate as to comparative importance from one who is well qualified and experienced in judging features which will most favorably influence night motor vehicle transportation. Dr. Forbes has devoted many years to the study of driving conditions, including human psychological and physiological factors. He has recently completed a report on some of the related aspects for the United States Bureau of Public Roads and the Automotive Safety Foundation.

We will watch for his follow-up on electronic computers and further developments which will furnish badly needed data for mathematical simulation of vehicle operation and, separately, traffic flow under night driving conditions. He says such simulation is being developed. We agree that "for accurate simulation of night driving conditions as well as for valid rating of roadway lighting, combination of the different visibility and visual comfort factors into ratings of a mathematical type will be basic."

We agree with Dr. Guth's suggestions, and will endeavor to achieve the high level of technical approach that he typifies. Comparisons of computations with actual observations are in process. Research is being stimulated to close the informational gaps.

Mr. Hardacre readily recognizes that number rating expansion of knowledge of fundamentals should be of great value in planning the required lighting for traffic problems involved: congestion, increased speed, etc. I have never known him to waver from the conviction that we must continue to improve techniques so as to more fully warrant the public enthusiasm. Pleasant attractive visual comfort conditions will help get roadway lighting *installed*. Only then is the visibility improvement made available to improve right traffic conditions. This points up the need for dual ratings for seeing.

Dr. Hopkinson's comments are typical of his correspondence, *i.e.* encouragement along with pertinent suggestions. We should profit by his statements, ". . . somewhat neglected the effects of glare and visual discomfort, which is not wise . . .", "wise in good time to stress the importance of visual comfort. . . ."

The Schouten effect should be the subject of detailed IERI-sponsored research directly related to roadway lighting and including some of the other effects of the brightness fluctuations encountered by the driver's travelling at speeds typical today. We heartily agree that tenths of a second might be critical.

Mr. Nagel continues to make engineering use of the data available, in his efforts to provide a roadway lighting "system which will give optimum over-all efficiency and result to the benefit of the roadway user."

Professor Putnam's studies, with the assistance of graduate students, have been indispensable to the ratings of relative visual comfort under roadway lighting conditions.

There are some portions of the driver's visual field which have brightness much lower than 0.1 footlambert. However, the pavement brightness ranges up to 0.7 footlambert and is prominent with respect to the driver's line of sight.

The field brightness question provides another opportunity of expressing the urgent need for instrumentation, such as that under development by Dr. Glenn Fry, which may be used to properly integrate the average field brightness. Vehicular traffic use should be a good basis for the priority on which field brightness should be investigated. Visual comfort driving conditions on residential streets are less important.

We are thankful for Professor Putnam's help and again advocate the continuance of his studies of relative comfort under roadway lighting conditions.

Dr. Spencer's laudable comments and interest are welcome. It would be nice if representative roadway lighting conditions were similar to interior practice so that the same data and methods would be applicable. However, some[9, 10, 12] are convinced that roadway lighting is more complicated and should be considered separately.

Field brightness is needed for practical purposes and representative ratings. Certain assumptions must be made, which we hope Dr. Spencer will find to be logical and useful.

The need for data under dynamic conditions has been stressed.

Texture or "hot-spots" in luminaire brightness is the subject of an IERI investigation by Dr. Fry. Reasonable variations in brightness are somewhat mitigated by the driver's attention being generally directed along the roadway rather than at the luminaires. Opinion as to tolerable luminaire brightness variations and representative source sizes might well include trial runs under typical roadway lighting systems.

When the luminaire source area is assumed to be uniform

*Sylvania Lighting Products, a division of Sylvania Electric Products Inc., Salem, Mass.
**Author.

the computation of the brightness of the luminaire source is obviously simplified. If the candlepower and other conditions remain the same, the relative visual comfort rating apparently decreases with size of source. For example, in the paper, for a single (No. 4) luminaire, ω in steradians is 0.00007 for 130-square-inch luminaire source viewed from a driver position at 0.5 MH transverse and 3.5 MH longitudinal distance. With field brightness of 1.0 footlambert, $\overline{B}_L$, the BCD brightness on the line of sight, is 743 footlamberts. $\overline{B}$ in position on the pole bracket at a viewing angle of 16 degrees has a BCD brightness of 743 $\times$ 1.95 (position factor) or about 1500 footlamberts. A smaller luminaire source will have a higher $\overline{B}$ or BCD brightness. ω for a 100-square-inch source is 0.00005 steradian and $\overline{B}$ is 1542. However, for the same luminaire candlepower from the smaller source B, the actual luminaire brightness is increased from 34,804 to 45,245 footlamberts. The ratio $\overline{B}/B$ for the single luminaire decreases, *i.e.* from $\frac{1500}{34,804} =$ 0.042 to $\frac{1542}{45,245} = 0.034$.

Dr. Spencer's questions with respect to the Luckiesh-Moss Visibility Meter have been previously discussed[6, 9, 10] at length by others. This meter is available.

It is hoped that Dr. Spencer will help answer the questions she raises regarding the procedure. Perhaps she will proceed with the application of the delos method to roadway lighting.

Mr. Trosper's excellent comments culminate in a suggestion for graphical presentation of specified limits, or tolerable range of relative visibility and relative visual comfort along a lighted roadway. Such charts will evolve from ratings for good roadway lighting practice. As usual, Mr. Trosper will contribute significantly to such ratings because of his interest in improving the public welfare through use of highly effective roadway lighting.

Mr. Wylie is also a constructive proponent of rapidly improving night driving conditions by means of good roadway lighting. Therefore, his question as to whether we intend that performance ratings for relative visual comfort and relative visibility be used for a rigid, inflexible field specification depends upon the unusual, seemingly undesirable circumstance which he has in mind.

We are also sure that he agrees that there should not be such large time gaps between knowing what should be done and doing it, especially when the public benefit is involved.

With this paper we not only provide a method for computing relative visual comfort and relative visibility, but also offer all data which we have available for this purpose. As a recipient of such data, Mr. Wylie knows that we will also supply it to any agencies "who wish to base their evaluations on the techniques developed in this paper. . . ."

In his usual succinct manner, Wilbur Smith, Traffic Consultant, says: "We are glad to have the materials which you sent us on the 'Computation of Relative Visual Comfort' as well as 'Relative Visibility Ratings for Roadway Lighting Systems.' This is a definite advancement and one which will be helpful to all of us."

The coast-to-coast interest in roadway lighting visual-traffic research by power company engineer-executives is notable. This is also borne out by power company contributions to the current studies on roadway lighting visibility being conducted by Dr. H. R. Blackwell.

Seagram Building Lobby

Because the 24-foot-high lobby is glass walled it "reads" as an integral part of the outside plaza and seems much more spacious than it really is. At night, this spaciousness is further accented by the wash of light, from recessed ceiling fixtures on dimmers, spilling over the travertine walls that enclose the elevator shafts. The ceiling is finished in gray glass mosaic, set in black cement. This beautiful surface mirrors the subtle coloring of travertine walls, floors and bronze columns.

Black louvers, which control the light, are designed by Isaac Goodbar, Illuminating Engineer, New York, N. Y. Photo and data courtesy Superior Electric Co., Bristol, Conn.

LIGHTING NEWS

Dr. N. A. Halbertsma Awarded IES Gold Medal

With the unanimous approval of Council, the IES Gold Medal and certificate this year has been awarded to the internationally renowned Prof. Dr. Ing. N. A. Halbertsma of Zeist, The Netherlands, Member Emeritus of the Society. Presentation of this, the highest honor in the field of illumination, will be made June 15 during the meeting of the Commission Internationale de l'Eclairage in Brussels, with some suitable recognition to be made also at the San Francisco Conference of IES in September. Canadian and Dutch delegations at the CIE, together with other friends of the medalist will join the United States National Committee for the presentation ceremony in Brussels.

N. A. Halbertsma

Although he first joined the Society in 1919, Dr. Halbertsma probably became best known to many of its members at the time of the 1928 National Technical Conference in Toronto and the CIE meeting which followed at Saranac Inn, N.Y. Fluent in a half-dozen languages, he was next to indispensable at these tri-lingual sessions, serving as the chief, though unofficial, translator of papers, reports and discussions. Highly knowledgeable, discerning and familiar with the lighting literature of the world, he continued in this role at subsequent CIE meetings, until simultaneous translation facilities were installed at Zurich in 1955. No one appreciated this service more than the Americans, who are frequently lacking in linguistic ability.

At the CIE meeting in Cambridge in 1931, Dr. Halbertsma was elected Vice-President, and in 1939 at Scheveningen he became President. Following the war, while still physically weakened by the deprivations of the Netherlands occupation, he set forth on travels to re-establish the National Committees. At Paris in 1948, he was re-elected and served with distinction as President through the Stockholm sessions in 1951. In recognition of his outstanding contributions, he was then made Honorary President of the CIE.

This by no means ended his service. He continued indefatigably to contribute his great abilities wherever he could be helpful. At Zurich in 1955 he gave the opening address, personally took care of all publicity and, with the assistance of Mr. Joh. Jansen, undertook the task of publishing the three-volume record of the Proceedings.

Dr. Halbertsma's contributions to the lighting field began in 1911, when he obtained his first patent, on a low-capacity arc lamp for projection service. The years that followed saw a constant flow of work on basic technology, design and application, which was reported in many papers, articles, brochures and lectures. An early paper presented an outline of an illuminating engineering course for technical schools; another proposed a diffusion factor which would characterize the distribution of light from reflecting surfaces. A book on industrial lighting was published in 1918.

Following the acquisition of his doctor's degree at Darmstadt, he became a lecturer at the Light Technical Institute of the Technical University of Karlsruhe, and in 1921 he returned to Holland to begin his career with the Philips Electric Lamp Works at Eindhoven. Here he soon assumed responsibility for the dissemination of information on lighting at both the technical and popular level, through publications, lectures and exhibits. He found opportunity also to design the lighting for expositions in several countries, notably those at Dusseldorf, Bern, Barcelona and Seville.

In 1939 he was appointed Professor of Illuminating Engineering at the University of Utrecht, where his inaugural address on quality in lighting anticipated much of the later-accepted concepts that quantity of light is not enough. In 1946 he became consulting engineer to the Netherlands Department of Public Works on the lighting of roads and ports.

Dr. Halbertsma has been a dynamic ambassador for lighting. He has lectured widely in numerous countries in Europe, South America and the Far East and in India. His gift for imaginative and interesting presentations has made him extremely effective with every type of audience.

He was one of the founders of the Nederlandsche Stichting voor Verlichtingskunde (the IES sister organization in Holland) and is a Membre d'Honneur of l'Association Francaise des Eclairagistes. In 1954, in recognition of his many and distinguished contributions to both the art and the science of illuminating engineering, Dr. Halbertsma was elected Member Emeritus of IES.

Back Issues of IE for Sale

Described as in excellent shape, well preserved, back issues of ILLUMINATING ENGINEERING and the *Transactions of the Illuminating Engineering Society* are up for sale. Those available are:

Transactions — Vol. 15, No. 2; Vol. 26, No. 1 through No. 10; Vol. 27, No. 7 and No. 8; Vol. 28, No. 9 and No. 10; Vol. 29, No. 1 through No. 7; Vol. 31, No. 7; Vol. 33, No. 1 through No. 10; and Vol. 34, No. 1 through No. 10.

ILLUMINATING ENGINEERING — Vol. 35 through Vol. 53 are complete except for January 1956 and December 1958. The Indexes from Vol. 38 through Vol. 52 are also available.

Price for the entire collection is $60. For further information write to E. L. Ehret, 431 South Douglas Ave., Belleville, Ill., who is giving up his IE library on leaving the lighting field.

(*News continued on page* 7A)

Here and There With I.E.S. Members

IES Lighting Handbook, Third Edition, just off the press, is presented to President George J. Taylor (second from left). Making the presentation is John J. Neidhart, Chairman, Handbook Revision Committee, with headquarters technical staff as pleased witnesses (C. L. Crouch, left; John Kaufman, right).

Contestants in Milwaukee Section's MMILJ Contest. Seated, left to right, E. H. Schaeffer, first place, Class II; Elsie Claiborne, first, Class I. Standing: Henry Koether, second, Class II; Henry Williams; Karl Hartwig, Contest Chairman; L. C. Odry, third, Class II; James Busam and Richard Barber. Another contestant, not shown here, was William Zimmerman, who left early to make the 100-mile drive home.

Golden Jubilee Dinner of the British IES was held February 9. Dignitaries in attendance included, left to right: photo at left, Dr. J. W. T. Walsh, O.B.E., Past-President, and President of the Commission Internationale de l'Eclairage; the Rt. Hon. the Earl of Mount Edgcumbe, an original member of the Society; photo at right, J. M. Waldram, Past-President; N. Boydell, Vice-President: L. J. Davies, Past-President; Prof. Dr. P. Schulz, Vice-President of Lichttechnische Gesellschaft e.V. Dinner meeting was at London's Criterion Restaurant.

East Central Sets Pace for 1959 Regional Conferences

Recipes for Regional Conferences are outlined in the Conference Guide. As with any "recipe," however, the cook makes a difference. For East Central Region's Conference in Baltimore, April 9-10, the guiding committee (see list) were mighty good cooks.

Some of the extras which contributed to its success are difficult to list — others are very concrete indeed. It is hard to measure the value, for instance, of the sincerity and earnestness of men like Mickey White, Conference Chairman; Chick Shotwell, RVP; and Paul Puckett, host-Section Chairman — and all of their committees. Carrying the recipe analogy still further, one might describe their invaluable contribution as that indefinable touch of a master chef. Better still, several of them.

There was nothing indefinable, however, about the program itself. Why *this* was so successful is easy to see. To begin with, it was obviously based on the premise that the men and women attending it should be able to gain something of real value to their jobs. A glimpse at a new concept (George Clark's lecture, for instance); ditto at current and future techniques (Nevin Weiss, Kaye Leighton, and W. H. Johnson); some inside information on new materials and their future in lighting — such as Dr. Witt's wonderful talk; a stimulating and open forum discussion on the hottest subject in lighting — new footcandle levels, their impact and their immediate practicality. A comfortable feeling of Society leadership and progress came from President Taylor's luncheon address. It would be fair to say that every delegate who heard this program learned something; and certainly safe to say that the two days and negligible expense was well worth it to their companies.

It's only too bad more people didn't hear it. Attendance was not high, for a Region whose membership totals 970. However, in addition to the 72 IES registered delegates, some 37 Baltimore and Washington consulting engineers, architects and others registered to hear the technical program specifically — in itself an indication of the program's excellence. In this investment of time, they too were well paid. Some 21 additional visitors attended the President's Luncheon only, and 31 out-of-town ladies participated in the Conference social program, for a total attendance figure of 161.

One deviation from the basic Guide which was especially successful, at this Conference at any rate, was its shortened and intensified format. The conference planners concentrated on three sessions, each of very special significance, with the second day paced to close the conference at one o'clock. Whether by chance or not is hard to say, but the result was a building effect — continuing to the climax of the final symposium. It's too bad a tape recording wasn't made of this. Some of the other talks will eventually appear in print — the "viewpoints and opinions" nature of this session has to be heard by the lucky few. Participants, who each discussed his own viewpoint and then formed a panel, were E. A. (Red) Linsday, General Electric, Nela Park; Willard Allphin, Sylvania Electric Products Inc.; and Berlon C. Cooper, *Electrical Construction and Maintenance* magazine (McGraw-Hill) — all canny thinkers

(*Continued on page* 9A)

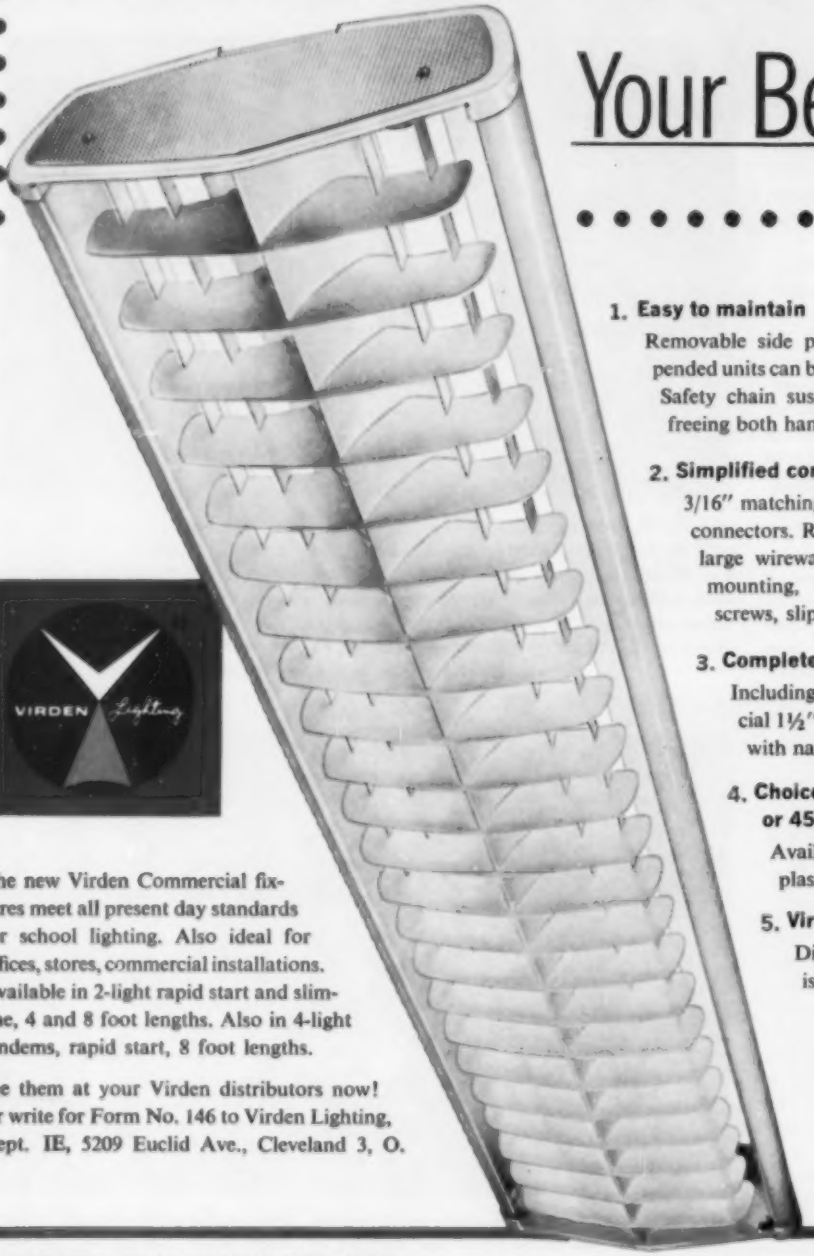
OPENING 1959's first Regional Conference in Baltimore, April 9-10, are, left, H. M. White, Conference Chairman; right, C. C. Shotwell, the Region's Vice-President. Pace-setting conference featured three technical sessions and outstanding "new footcandles" symposium. Also taking part in the opening ceremonies, with welcomes to the delegates, were C. B. Hellmann, former Secretary of State of Maryland, and C. P. Crane, Chairman of the Board, Baltimore Gas and Electric Co.

WORKHORSES of the East Central Region (Section/Chapter officers) plotted future programs throughout the evening of April 8, at a Regional Activities meeting. Participating also (far background) are A. D. Hinckley, IES Managing Director and G. J. Taylor, President.

Five distinctive features

make this new VIRDEN Commercial Fixture

Your Best Buy!



1. **Easy to maintain**
   Removable side panels. No tools required. Suspended units can be relamped from above or below. Safety chain suspends louvres out of the way, freeing both hands for maintenance.

2. **Simplified continuous row installations**
   3/16" matching K.O's. in end plates eliminate connectors. Rectangular K.O's. provide extra large wireway for easier wiring. For stem mounting, mounting plates have preset screws, slip into key holes in channel.

3. **Complete mounting accessories**
   Including rigid and swivel stems plus special 1½" on-ceiling outlet box to comply with national code.

4. **Choice of 35° x 25°, 35° x 45°, or 45° x 45° shielding**
   Available in metal or polystyrene plastic side panels.

5. **Virden quality throughout**
   Die stamped steel. Bonderized finished in white high-baked enamel.

The new Virden Commercial fixtures meet all present day standards for school lighting. Also ideal for offices, stores, commercial installations. Available in 2-light rapid start and slimline, 4 and 8 foot lengths. Also in 4-light tandems, rapid start, 8 foot lengths.

See them at your Virden distributors now! Or write for Form No. 146 to Virden Lighting, Dept. IE, 5209 Euclid Ave., Cleveland 3, O.

Find Your Nearest Dealer In The Yellow Pages

VIRDEN LIGHTING . . . Division of John C. Virden Company • Cleveland 3, Ohio

Member American Home Lighting Institute

TECHNICAL highlight which will be hard to beat was this Symposium on current lighting levels. At the open forum following the Symposium: Berlon Cooper, Associate Editor, *Electrical Construction and Maintenance*; E. A. Linsday, General Electric; G. J. Taylor, IES President; Willard Allphin, Sylvania. At right is Chairman-Moderator, John Frizzell, Pittsburgh Reflector Co.

(*Continued from page* 7A)

and each close to his own phase of the quantity and quality of illumination and its practical application. George Taylor, IES President, gave a summation of the three talks, joining the panel also. It must have been with a feeling of real satisfaction and pride that RVP Shotwell formerly adjourned the conference at the end of this four-hour session.

And one more thing. All the sessions were on time:

Wednesday Evening, April 8th

Local Activities Meeting
Get Acquainted Party

Thursday Morning, April 9th

Opening Ceremonies
Conference Called to Order — H. Mayhew White, General Chairman of Conference.
Maryland Welcome — C. B. Hellmann, former Secretary of State of Maryland.
Industry Welcome — Charles P. Crane, Chairman of Board, Baltimore Gas and Electric Co.
Regional Welcome — C. C. Shotwell, Vice-President, East Central Region.
First Technical Session
Chairman — Alfred J. Rugo, Chairman, Capital Section.
Considerations in Lighting and Wiring the New Social Security Administration Building — Nevin Weiss, Whitman, Requardt & Associates, Consulting Engineers.
Aesthetic and Psychological Aspects of Lighting — George W. Clark, Sylvania Lighting Products.

Thursday Afternoon

President's Luncheon — Chairman, Thomas P. Harris, Jr., Virginia Section.
Address by George J. Taylor, President I.E.S.
Second Technical Session
Chairman — Thomas G. Broussard, Philadelphia Section.
International Standards and Physical Properties of Plastics — Dr. Ralph K. Witt, Johns Hopkins University.
Regional Competition — My Most Interesting Lighting Job.

Thursday Evening

Reception
President's Dinner-Dance
Master of Ceremonies — H. Mayhew White, General Chairman.
Presentations — Paul J. Puckett, Chairman, Maryland Section.
MMILJ Awards — C. C. Shotwell, Regional Vice-President.

Friday Morning, April 10th

Third Technical Session
Chairman — Richard J. Pretzman, Eastern Pennsylvania Section.
New Concepts in Residential Lighting — Miss Kaye Leighton, General Electric Co., Cleveland, Ohio.
High Frequency Operation of Fluorescent Equipment — W. H. Johnson, Westinghouse Electric Corp.
Symposium
Chairman — John S. Frizzell, Pittsburgh Section.
Concepts of Lighting Today and Tomorrow — E. A. Linsday, General Electric Co., Cleveland, Ohio. Chairman, IES Progress Committee.
Caution in New Lighting Advances — Willard Allphin, Illumination Research, Sylvania Lighting Products, Inc.
Are Higher Lighting Levels Now Practical? — Berlon C. Cooper, Associate Editor, *Electrical Construction & Maintenance.*
Summation — George J. Tayor, President, I.E.S.

MMILJ Contest

Other Regions begin to get a notion of their national competition, with this first Regional contest. Both classes, residential and commercial, will have winners from East Central. Judges of both contests allowed as how it was too bad they couldn't declare at least two First Prizes. Their judgments, however, were as follows:

Class I — Residential

First Prize: S. Ehrlich, Maryland Section, "Using Lumen Counter Method."
Second Prize: Ben Goodman, Capital Section, "Lighting a Garden Show Exhibit."
Third Prize: Jack Laughner and W. H. Roll, Pittsburgh Section, "Good Lighting and the Home Builder."

Class II — Commercial

First Prize: Armand Zitelli, Pittsburgh Section, "Social Club Meeting Room."
Second Prize: Paul F. Kyack, Philadelphia Section, "Church of the Nazarene."
Third: A. A. Fox and Mark Harris, Capital Section, "Walsh Memorial Building."

(*Continued on page* 10A)

BEAU GESTE **— First Lady receives miniature Virginia state flag, a gesture of honor, by Luther Reams, Secretary of the Virginia Section.**

COMMERCIAL, Class II contest: Mark Harris and Al Fox, joint entries from Capital Section; Armand Zitelli, Pittsburgh Section; Paul Kyack, Philadelphia Section and Leo Ratterman, Maryland Section.

SAN FRANCISCO-bound Armand Zitelli, Class II winner, receives check and kudos from RVP Shotwell.

JUDGES having a hard time with three excellent Class I entries are, l. to r., Kaye Leighton, Katherine Goodall, Ruby Redford.

(Continued from page 9A)

Fourth: Leo Ratterman and D. C. Bankie, Maryland Section, "Auditorium for an Appliance Warehouse."

Judges were: Class I — Kaye Leighton, General Electric Co., Nela Park; Katherine Goodall, Philadelphia Electric Co., and Ruby Redford, IE Editor.

For Class II — George Clark, Sylvania Lighting Products, Inc.; Berlon Cooper, *Electrical Construction and Maintenance;* and Ray Teele, U. S. Bureau of Standards.

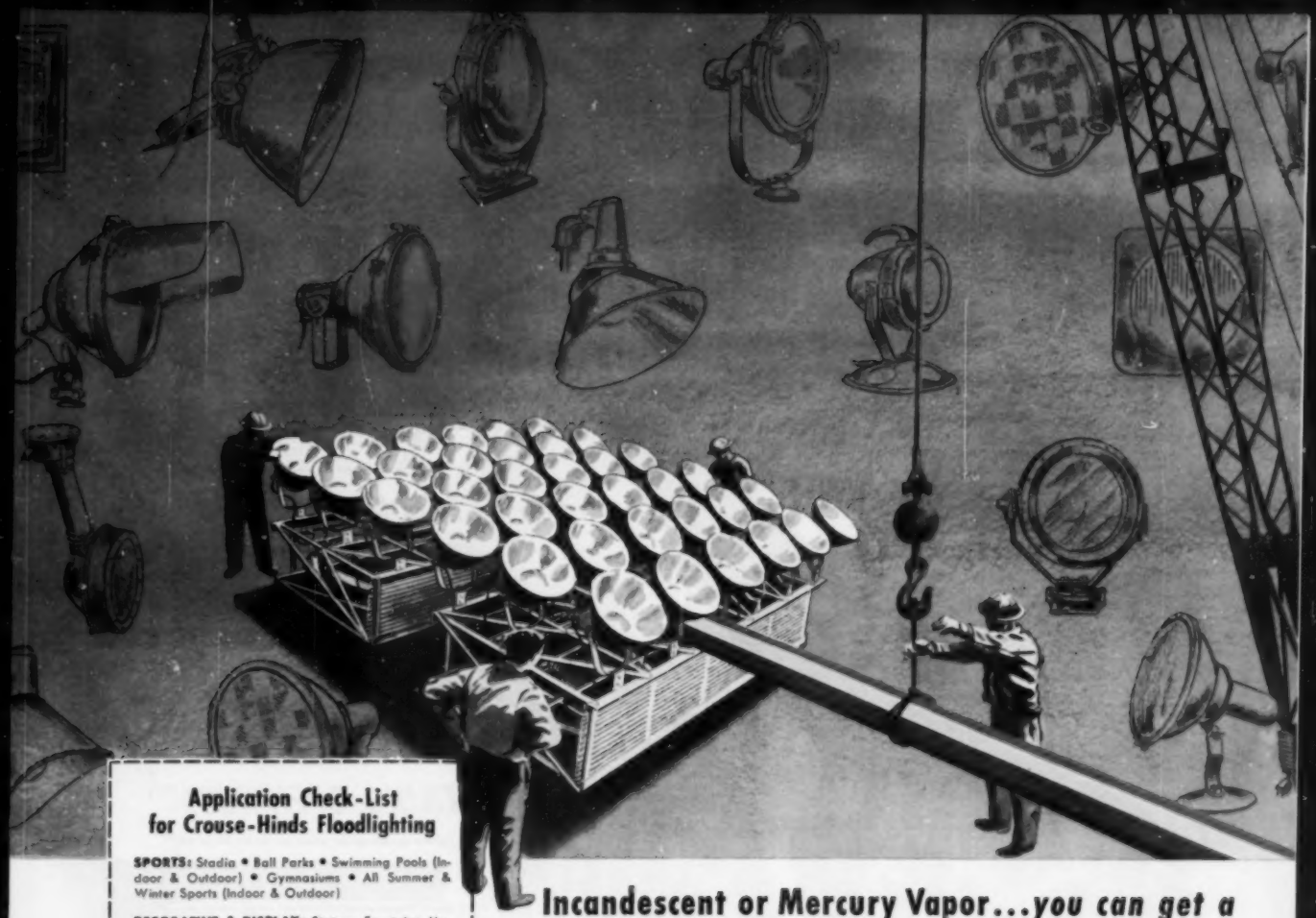
Social Program

The Papers program was too good at this Conference to lure *any* of the men away from the lecture hall, but 31 ladies thoroughly enjoyed the program planned

(Continued on page 14A)

RESIDENTIAL My Most Interesting Lighting Job competition was by, left to right, Jack Laughner, Pittsburgh Section; Ben Goodman, Capital Section and Si Ehrlich (far right), Maryland Section. Tom Broussard, contest chairman is second from right.

CLASS I first prize to Si Ehrlich. Messrs. Ehrlich and Zitelli (above) will represent the Region in the National Contest next September.



Application Check-List for Crouse-Hinds Floodlighting

SPORTS: Stadia • Ball Parks • Swimming Pools (Indoor & Outdoor) • Gymnasiums • All Summer & Winter Sports (Indoor & Outdoor)

DECORATIVE & DISPLAY: Statues, Fountains, Memorials & Monuments • Public Gardens • Building Fronts & Entrances • Park, Playground & Cemetery Entrances & Interiors

BUSINESS: Shopping Areas • Drive-Ins, Outdoor Theaters • Building Fronts & Entrances • Recreation Parks • Gas Stations

AIRPORT: Ramps • Boarding & Loading • Street & Road Approaches to Airport • Markers & Beacons • Emergency Portables

CONSTRUCTION: Roads & Streets • Dams, Seaways & Piers • Detours • Buildings • Reconstruction of Disaster Areas

INDUSTRIAL AND UTILITY: Parking Areas • Freight Yards • Weigh Stations • Docks & Piers • Staging Areas • Production Work Areas

TRAFFIC: Tunnels • Viaducts • Bridges • Underpasses • Walks • Public Squares, Thruway Interchanges & Rest Areas • Cloverleafs • Parking Areas

UNDERWATER: Swimming Pools (Indoor & Outdoor) • Marine Life Displays • Municipal Garden Pools • Aquariums • Divers' Portable Units

HAZARDOUS: Explosion-Proof Lighting for: Petroleum Refineries • Chemical Plants • Explosive Plants • Service Stations

SPECIAL PURPOSE: Plant Protection (Floodlighting for Safety) • Estate Lighting • Portable Floodlighting for Parades, Bandstands, etc.

Incandescent or Mercury Vapor...*you can get a*

CROUSE-HINDS Floodlight ...for every possible application

Name your floodlighting need – for construction, emergency, utility, traffic, display, decoration, sports, underwater, or hazardous-area use. Crouse-Hinds can supply floodlights *designed specifically for each application.*

A quick scanning of the widely varied applications included in the Check-List at left proves again that floodlights often provide *better light from few source points at less cost* than conventional lighting.

For the broadest experience and skill in every conceivable situation where floodlighting may be of use . . . call on Crouse-Hinds. Our field engineers will gladly assist with your planning. Just call your Crouse-Hinds distributor, or the nearest sales office or representative listed below.

Send us a brief description of your lighting problem, or an indication of the floodlight types in which you are interested. We will send literature containing product information applying to your problem by return mail.

A NATIONWIDE DISTRIBUTION exclusively through ELECTRICAL DISTRIBUTORS

CROUSE-HINDS COMPANY

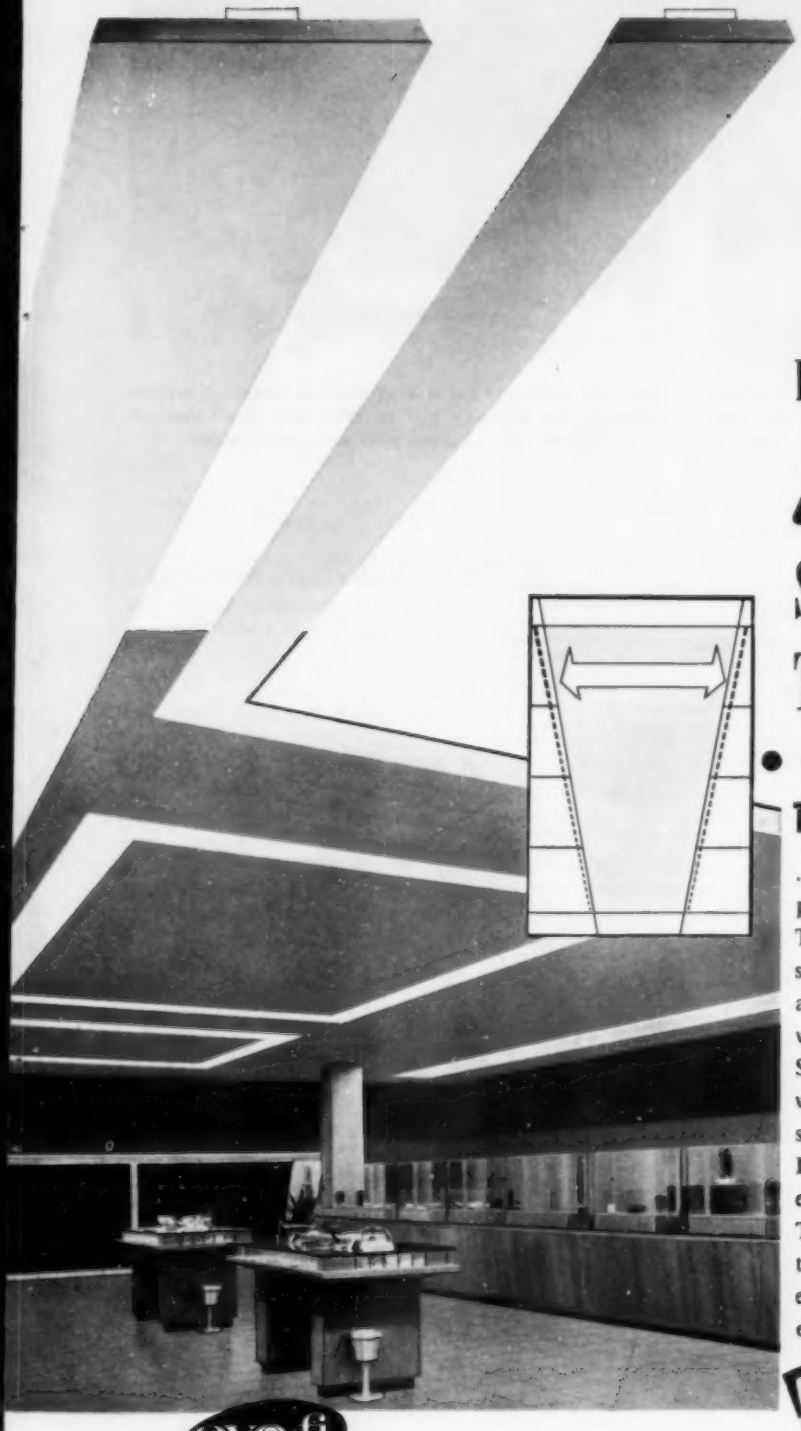
Main Office and Factory: Syracuse, N. Y.
Crouse-Hinds Company of Canada, Ltd., Toronto, Ont.

Offices: Baton Rouge Birmingham Boston Buffalo Chicago Cincinnati Cleveland Corpus-Christi Dallas Denver Detroit Houston Indianapolis Kansas City Los Angeles Milwaukee New Orleans New York Philadelphia Pittsburgh Portland, Ore. Salt Lake City St. Louis St. Paul San Francisco Seattle Tulsa Washington RESIDENT REPRESENTATIVES: Albany Atlanta Baltimore Charlotte Chattanooga Jacksonville Reading, Pa. Richmond, Va. Shreveport

"SPEEDOMATIC'S NEW EXCLUSIVE TELESCOPIC DOOR FRAME REALLY STRETCHES TO FIT IRREGULAR CEILING OPENINGS!"
"LOOK HIGH and LOW—YOU, TOO, WILL AGREE THAT THE NEW SPEEDOMATIC IS THE MOST VERSATILE, FASTEST-INSTALLING and BEST-LOOKING TROFFER on the MARKET TODAY!"

new *Smithcraft* SPEEDOMATIC TROFFERS SIMPLICITY ITSELF TO SPECIFY AND ORDER! The four basic types of Speedomatic troffers fit all of today's popular ceilings — and Smithcraft's *complete Ceiling Index* indicates the type of troffer to order for perfect installation in any ceiling system.

"BY GEORGE, IT IS ONLY 4 15/16" DEEP - SAVES CONSTRUCTION COSTS!"



new Smithcraft SPEEDOMATIC TROFFERS

• • • WITH THE EXCLUSIVE TELESCOPIC DOOR FRAME

. . . that automatically expands or contracts to assure perfect fit even in irregular ceiling openings. The shielding medium is framed in the ceiling by a single width of metal, offering maximum illumination area and a clean, precise finished ceiling appearance, with no visible bolts, hinges, catches, etc. All of Smithcraft's complete series of one-foot and two-foot wide Speedomatic troffers are extremely easy to specify from Smithcraft's complete Ceiling Index. Installation of Speedomatic troffers is fast and efficient — the only tool needed is a screwdriver. Troffer installs in seconds from below by fast travelling levelling screws. Doors open and close easily, without mechanical catches, for easy maintenance.

For complete information on today's fastest-installing troffers, write for Smithcraft's Speedomatic folder. Also contains complete Smithcraft Ceiling Index and shielding information.

eye-fi RE/LIGHTING

America's finest fluorescent lighting **Smithcraft Lighting** CHELSEA 50, MASS.

MRS. TAYLOR (photo at left) beams, as she displays her gift from the Region, a silver plate engraved with the appropriate names and dates. In photo at right, Paul J. Puckett (center), Chairman of the host Maryland Section, presents the Region's gift to RVP and Mrs. Shotwell. Inside this package, too, was a silver plate.

(Continued from page 10A)

for them by Mrs. C. E. Sparrow, Jr., Chairman. In an early Spring heat wave (92° F), they toured Annapolis, even catching a dress parade of the midshipmen, and had luncheon at the Annapolis Yacht Club. Another trip took them to Hammond Harwood House also in Annapolis, a beautiful example of pre-revolutionary architecture and furnishings. Still others included, Walters Art Gallery, Peale Museum, and a mass shopping binge in Baltimore.

Two gay evenings were part of the program, both of these for ladies and gentlemen. One was a pre-conference "Get-Together" the night before the conference, which turned out to be exactly that. It was such a nice party everyone was loathe to end it, and smaller groups of new and old friends continued the fun in many a suite. Highlight, of course, was a dinner-dance, April 9, which made no small contribution to the feeling of "this-is-a-wonderful-conference-don't-you-think." Guests of honor, of course, were President and Mrs. Taylor (a *popular* couple!). Master of Ceremonies was General Chairman White; C. C. Shotwell presided at the MMILJ Awards, and host Paul J. Puckett for the gift presentations. This latter was a warm happy moment. As a memento of their first 1959 Regional Conference, President and Mrs. Taylor were presented with a silver plate engraved with date and occasion. The Shotwells also, for this their final Regional Conference as Regional Vice-President, received an engraved silver plate. Warm and happy, indeed, and one might add, gay.

The following are some of the people who made this possible:

CONFERENCE COMMITTEE

C. C. Shotwell	Regional Vice-President
H. M. White	General Chairman
P. J. Puckett	Chairman, Maryland Section
C. E. Sparrow, Jr.	Registration
S. Masland	Program
P. K. Allen	Publicity
R. C. Desor	Transportation
R. Dunlop	Finance
S. E Ehrlich	Arrangements
J. C. Burdette	Hotel
Mrs. C. E. Sparrow, Jr.	Ladies

SECTION CHAIRMEN

A. J. Rugo	Capital
P. J. Puckett	Maryland
J. S. Frizzell	Pittsburgh
R. J. Pretzman	Eastern Pennsylvania
T. G. Broussard	Philadelphia
T. P. Harris, Jr.	Virginia

Advanced Lighting Seminar Offered in Florida

Under the co-sponsorship of the Florida Section of IES and the Lighting Department of the Tampa Electric Co., a seven-week advanced lighting seminar is being conducted in Tampa, Fla. The two-hour meetings are held on Wednesday nights at the Tampa Chamber of Commerce Auditorium.

Program is as follows:

March 11 — Light and Sight — Dr. Alvin Frey, Optometrist.
March 18 — Light Sources, M. L. Harkey, General Electric Co., Lamp Division.
March 25 — Illumination Design — Paul Harrison, Sylvania Electric Products, Inc.
April 1 — Office and Store Applications — Fred Guth, Edwin F. Guth Co.
April 8 — Industrial and Floodlighting Applications — T. Bradford, Benjamin Electric Mfg. Co.
April 15 — Lighting Maintenance — Malgar Gray, Fluorescent Lighting Service.
April 22 — Luminous Ceiling Applications — Walter Toley, Columbia Electric Co.

Graduation and the awarding of certificates is scheduled for the last meeting of the seminar. Attendance for the seven sessions is expected to average 100.

Membership Committee Reports March Standings

According to J. C. Forbes, Chairman of the National Membership Committee, the figures as of March 26 show a ten per cent increase in over-all Society membership since October 1958, with about 125 new members each month. In the various intra-Society membership contests, the Canadian and South Pacific Coast IES'ers are out front in all categories. To wit:

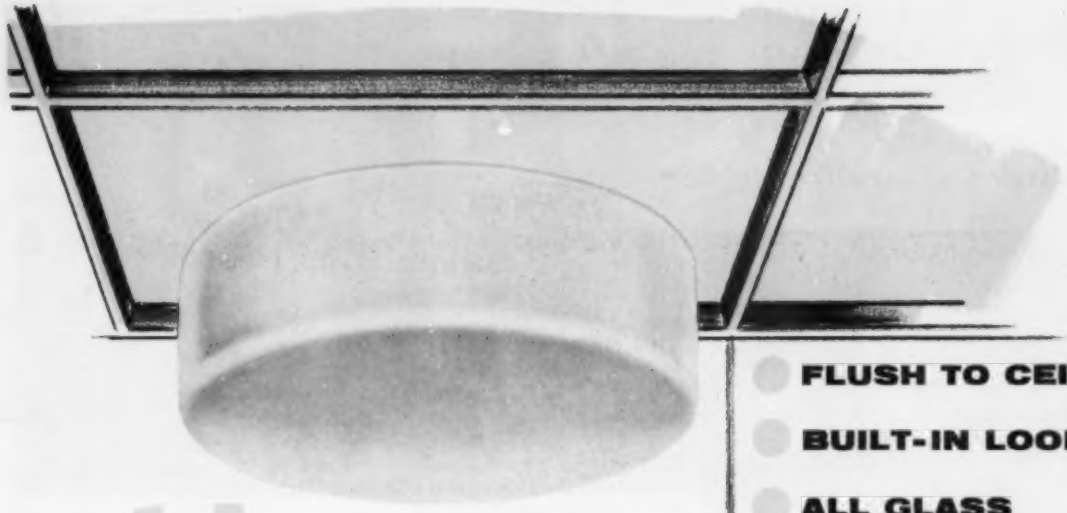
- Regional Contest — Canadians are on top, with South Pacific Coast second.
- Section vs. Section — San Diego in first place, San Jose, second and British Columbia third.
- Chapter vs. Chapter—New Yosemite Chapter leading, Quebec second and Winnipeg third.

BRI Studying New IES Recommendations

A two-day Conference of the Building Research Institute, to study the new IES recommended illumination levels in relation to the building industry, is being held at the Statler-Hilton Hotel, Cleveland, Ohio, on May 20-21.

Dr. H. Richard Blackwell opens the meeting with a discussion of the research

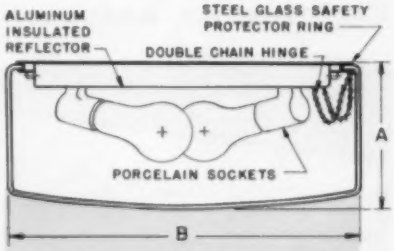
(Continued on page 17A)



Klondike

by PERFECLITE

- **FLUSH TO CEILING**
- **BUILT-IN LOOK**
- **ALL GLASS**
- **ALL LIGHT**



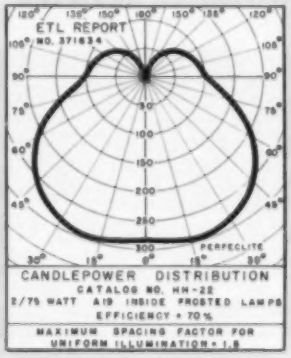
No metal shows, nothing projects on the Klondike*, Perfeclite's latest incandescent ceiling unit. Mounted absolutely flush, it allows maximum utilization of the opal globe for the highest light efficiency available . . . gives that built-in look without costly recessing.

The globe opens on a double chain hinge for quick, easy cleaning and relamping . . . is secured in place again with a simple twist of the wrist by a unique patented locking device. Interior construction is of 20-gauge steel. The reflector is faced aluminum. The multiple porcelain sockets are equipped with #18 A F leads for direct connection to Types R, TW or any 60° C rated wire.

Here at last is a totally new concept in fixture design . . . a totally new way to provide better lighting for either commercial or residential interiors. For further information, mail the attached coupon today!

Units are Underwriters' Laboratories, Inc., approved.

Cat. No.	Wattage	A	B
HH-21	2-60W	5⅛"	10"
HH-22	2-75W	5⅜"	12"
HH-23	2-100W	6⅛"	14"
HH-24	3-100W	6⅝"	16"



*Patented

THE **PERFECLITE** COMPANY
1457 East 40th Street • Cleveland 3, Ohio

THE PERFECLITE COMPANY
1457 East 40th Street • Cleveland 3, Ohio
Please send me the Perfeclite Data Sheet 59-C.
NAME _____
ADDRESS _____
CITY _____ STATE _____

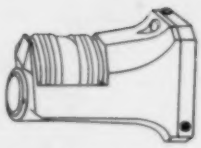
Revere Outdoor Lighting Report

Revere ELECTRIC MFG. CO.

Lighting a church exterior

The Problem: To provide distinctive, dramatic lighting for a church exterior. Fixtures must have wide, even light patterns and must be attached to the building itself.

The Solution: Revere No. 3151-A Underneath Floodlights were selected for their wide, flat light pattern. Because they are attached directly to the building, eliminating overhead arms, these underneath light fixtures are unobtrusive and blend in with architectural lines of the building. They are completely weather-tight.

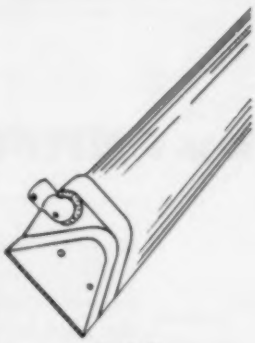


No. 3151-A
Underneath Floodlight

Lighting an automobile dealership

The Problem: To highlight the front of an automobile showroom exterior, showing to best advantage the face of the building and its distinctive identification.

The Solution: A continuous line of Revere Fluoresign luminaires were installed at cornice height, running the entire length of the surface to be lighted. The integral luminaires have an adjustable feature which permits accurate placement of light for smooth, even lighting. Enough spill light occurs on sidewalk for inviting atmosphere.



No. 8600
Fluoresign Luminaire

Lighting a service station

The Problem: To put an extremely high level of light on a service station's pump islands and service areas. Station must be unusually attractive to meet competition.

The Solution: Two Revere No. 7420 luminaires with 1000-watt color-improved lamps are mounted at a 14-foot height on each island. These provide a maintained average of 60 footcandles in the service area. Eliptor floodlights illuminate perimeter. High level of illumination has greatly improved station's competitive position.

No. 7420
Mercury Floodlight

Write for Revere's complete catalog of outdoor lighting equipment.

Revere ELECTRIC MFG. CO.

OUTDOOR LIGHTING

Revere Electric Mfg. Co. • 7420 Lehigh Avenue • Chicago 48, Illinois (In suburban Niles)
Long Distance Phone: NIles 7-6060 • Chicago Phone: SPring 4-1200 • Telegrams: WUX Niles
In Canada: Curtis Lighting, Ltd., Leaside, Toronto, Ontario

KEYNOTE address, at the National Lighting Exposition, held March 1-4 at the New York Coliseum, was given at the opening session by George J. Taylor, IES President (photo at left). There were over 200 exhibits at the show including one for the Society, here manned by C. E. Ellis (left), IES Advertising and Promotion Manager.

(Continued from page 14A)

which formed the basis for the revised recommendations. C. L. Crouch, Technical Director of IES follows with an explanation of the Society's interpretation of the Blackwell findings and a review of the resultant recommendations.

Other topics under discussion at the Conference include: trends in light source development and utilization, effects of higher levels on air conditioning and noise control, operating and maintenance costs and the use of light as an element of architectural design.

A tour of the General Electric Lighting Institute at Nela Park with demonstrations of the new illumination levels and the latest design trends is also on the program.

New Englanders Study Federal Highway Program

Suggested speeds on the highways being built under the Federal Highway Development Program are 70 mph in rural areas, 50 mph in urban locales. For good nighttime visibility and safe driving conditions under these speeds, efficient roadway lighting is a necessity.

To study the effects of the highway program on states, cities and the economy in general, and on the electric industry in particular, the New England Section of IES and the Electric Institute, Inc. held a joint special meeting on April 13, at the University Club in Boston, Mass.

R. P. Agnew, public roads engineer with the Bureau of Public Roads, Albany, N. Y. (headquarters for Region I which encompasses the New England area) was the featured speaker at the meeting which included in its attendees government highway and safety officials, traffic engineers, insurance company safety engineers, utility and manufacturer personnel and others interested in vehicular and pedestrian safety.

The network of U. S. Routes being constructed under this program is intended to form the "Main Street" of the United States, linking 90 per cent of the cities with a population of 50,000 or more.

Attendance Nearly 17,000 At National Lighting Exposition

Attendance reported for the Second National Lighting Exposition, held March 1-4, 1959 at the New York Coliseum, totaled 16,796, an increase of more than 35 per cent over that of the first such show last year. A breakdown of registration by industry or occupation shows that, again, the largest representation was by electrical wholesalers, contractors, engineering firms, architects and designers, decorators, consultants.

Occupation or Industry	Registration
Electrical wholesalers	3199
Electrical contractors	2377
Electrical engineering firms	2037
Architects and designers	2331
Decorators	1052
Consultants	1006
Builders	1022
Education	142
Government	304
Manufacturers	995
Utilities	292
Purchasing Agents	258
Representatives of foreign countries and purchasing agents	526
Miscellaneous	1255
TOTAL	16,796

Statistics show also that, geographically, the enrollment came from almost every state in the country, including

(Continued on page 18A)

1959 Regional Conferences Still to Come

Region	Place	Date
Pacific Northwest	Banff Springs Hotel Banff, Alta.	May 26-30
Northeastern	Curtis Hotel Lenox, Mass.	June 4-5
Canadian	Chateau Laurier Ottawa, Ont.	June 11-12
Great Lakes	Lafayette Hotel Buffalo, N. Y.	June 22-23

(Continued from page 17A)

Hawaii; also from Canada; Mexico and many European, Asian and South American countries.

The twelve panel discussions (for program, see page 9A, February IE) forming the technical symposium were also highly successful and well attended. Transcripts of these discussions are now being made available at the office of the National Lighting Exposition, 550 Fifth Ave., New York, N. Y., at a nominal service charge for handling.

Penn State to Hold Management Seminar

A seminar in research and development management is being planned by the Pennsylvania State University Extension Center to provide management training especially for engineers and scientists who have been, or expect to be elevated to executive positions. The seminar is scheduled for July 5-10, 1959, and will feature lecture and workshop sessions devoted to such topics as the development of administrative skills, the role of management, leadership, motivation, rating, training and communication.

Inquiries regarding registration and a more detailed account of the program should be addressed to Extension Conference Center, Pennsylvania State University, University Park, Pa.

Chicago Lighting Institute Spring Program

Continuing its program of lighting education in the Chicago area, the Chicago Lighting Institute has scheduled again this spring, its basic lighting courses. Lighting Fundamentals, including both lecture and laboratory sessions, is taught by Raymond E. Wozniak; Frank R. McShane presides over Wiring Design No. 1. Both courses run for 12 weeks; the fee is $25 for each.

In addition to these courses, the Institute, in conjunction with the Electrical Contractors' Association of Chicago, is planning a full-day lighting clinic aimed specifically toward electrical contractors. This clinic, the first to be organized with the cooperation of the Contractors' Association, is scheduled for May 5.

Program is as follows:

Morning Session

Chairman — J. W. Collins, Electrical Contractors' Association, City of Chicago.
Light in Action — C. W. Zersen, Managing Director, Chicago Lighting Institute.
Seeing Research and Efficiency — R. D. Bradley, Day-Brite Lighting, Inc., St. Louis, Mo.
Light Sources the Electrical Contractor Should Know About — R. E. Wozniak, Chicago Lighting Institute.
Benefits of Planned Lighting — Charles Wallace, Curtis Lighting, Inc., Chicago.
Discussion Period.

Afternoon Session

Chairman — J. J. McLaughlin, Kelso-Burnett Electric Co.; Chairman Chicago Section IES.
The Latest in Industrial Lighting — Eldon Witte, Benjamin Electric Manufacturing Co., Des Plaines, Ill.
The Modern Store — Where You Merchandise with Light — Rex Zinn, Sunbeam Lighting, Inc., Gary, Ind.
Making Your Efforts Pay Off — Edward Themak, Jr., General Electric Co., Cleveland, Ohio.
Selling the Customer on "Light That Is Right" — J. A. Schneller, Quadrangle Manufacturing Co., Chicago, Ill.
Discussion Period.

How To Be a Success

What makes a successful *young* engineer? What characteristics should a company look for in hiring the engineering graduate? The results of a year's "Personal Follow Program" conducted by the Westinghouse Electric Corp. which studied 1200 engineers with experience ranging from one to six years indicates that spatial vision, advanced engineering and quantitative ability are the three most important factors in engineering success.

Eighty-nine per cent of the 1200 men studied have "Spatial Vision Scores" about 175 points above the national mean, indicating a high ability to translate the spoken word and analytical terms into three-dimensional objects. "Advanced Engineering Scores" of the group were 100 points above the national average and "Quantitative Ability Scores" showed the engineers exceeding the average by 133 points. This would seem to indicate that these two factors are also keys to engineering ability.

The results of this study were reported at a meeting of the American Institute of Electrical Engineers by G. E. Moore, manager of graduate student training for Westinghouse. Mr. Moore stated that motivation seems to be a strong factor in the careers of the beginners, noting many cases where men with unexceptional college records who received encouragement in their jobs began to excel.

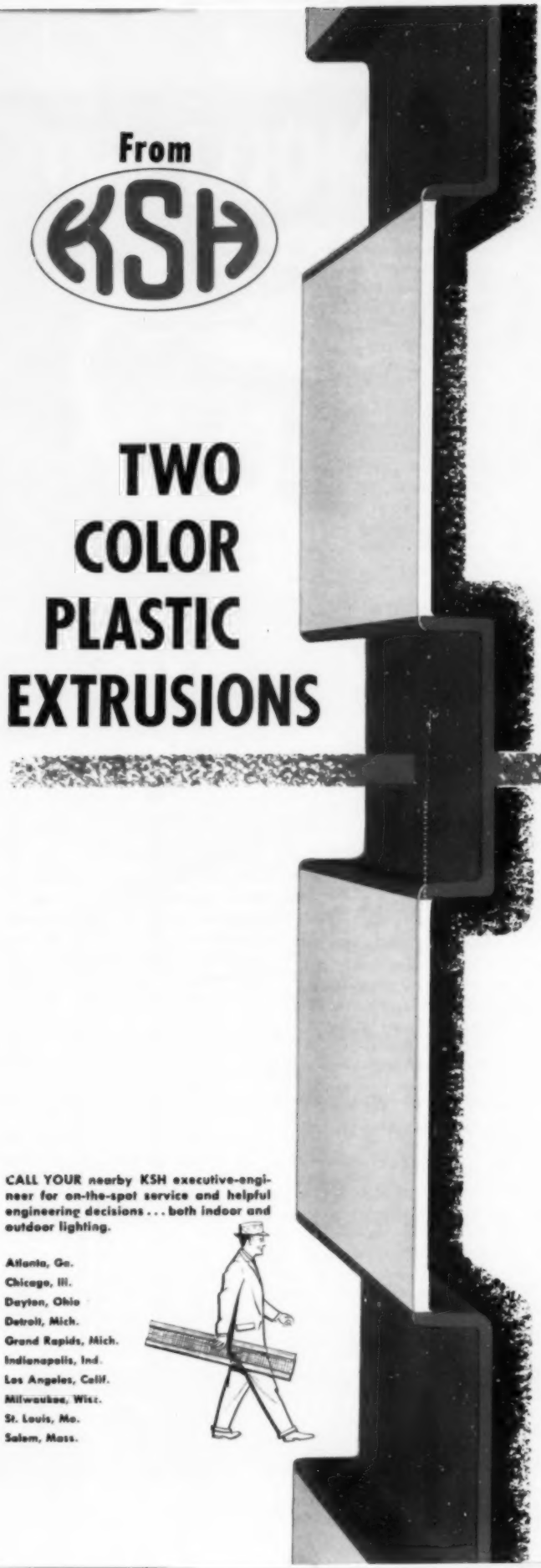
Contrary to popular belief, and to the

(Continued on page 20A)

That's Fester's way of reminding the City Council that we need better street lighting.

From KSH

TWO COLOR PLASTIC EXTRUSIONS



with

SOLID COLOR PENETRATION

no scratch through

permanent coloring

CALL YOUR nearby KSH executive-engineer for on-the-spot service and helpful engineering decisions . . . both indoor and outdoor lighting.

Atlanta, Ga.
Chicago, Ill.
Dayton, Ohio
Detroit, Mich.
Grand Rapids, Mich.
Indianapolis, Ind.
Los Angeles, Calif.
Milwaukee, Wisc.
St. Louis, Mo.
Salem, Mass.

KSH PLASTICS, INC.
HIGH RIDGE, MISSOURI

(Continued from page 18A)

surprise of those conducting the program, environmental factors such as the color of the walls, amount of desk space, etc., were not influencing motivation factors.

Analysis of the data collected in the study is being continued, and the company expects further information to be revealed.

ISCC Godlove Award To Ralph M. Evans

Ralph M. Evans, Director of the Color Technology Division, Eastman Kodak Co., Rochester, N. Y., has been selected as the second recipient of the Inter-Society Color Council Godlove Award for outstanding contributions to the knowledge of color in science, art and industry. The Award was presented to Mr. Evans by ISCC President Walter C. Granville at the banquet held during the Council's 28th Annual Meeting in New York City on April 1.

A Past President of the ISCC and, at present, Secretary of the Council, on which he represents the Society of Motion Picture and Television Engineers, Mr. Evans is an expert in the fields of color and color photography. He is the author of numerous publications, including the book, *An Introduction to Color.*

The Godlove Award is highly unusual in form, consisting of a plastic prism in which is embedded a gold diffraction grating which produces all the colors of the spectrum.

Permagon Institute Offers Russian Lighting Code

The English translation of the Russian Lighting Code, including "Building Norms and Rules" and "Classification of Visual Tasks," has been made available by the Permagon Institute. Copies may be secured from the Institute's New York office, 17 East 54th St., New York 22, at a cost of $20.

The translation, in mimeographed form, includes recommended illumination levels for industrial passageways, public buildings, residential and outdoor areas. Sample levels, in lux, are: Industrial passageways with heavy traffic — 3; offices — 200 with fluorescent, 75 with filament; libraries—300, fluorescent, 100, filament; operating rooms—400, fluorescent, 200, filament; hostels and boarding-houses — 100, fluorescent, 50, filament; main streets in capitals of Union Republics, major industrial cities — 4.

The translation of the Code, originally published in the Soviet magazine, *Svetotekhnika,* is available for inspection at IES headquarters.

From the Desk of the President

We are well on our way into the third quarter of the Society's yearly operation. There are a few things I would like to report to you in our progress for the first half year's activities. Some of these things have turned up in my previous monthly reports. But an over-all look at our accomplishments may be of interest.

Of significant importance are the projects that Dex Hinckley, as Managing Director of the Society, has been undertaking. To mention a few, the coordination of Senior Staff activities has been approached through some five meetings with all Senior Staff present and some dozen conferences with individual staff members. Subjects discussed range from long-range program planning to the immediate problems of office operation. A revision of our telephone service is an example.

His assistance and greater participation in Council and Council Executive Committee meetings has been most helpful, with principal effort directed at the careful preparation of material in the agenda for meetings. Moreover, his activity and counsel at many Standing and General Committee meetings has become possible since the employment of John Michel as Office Manager. In long-range planning, Mr. Hinckley has studied and prepared reports to the officers and Council on IES participation in the United Engineering Center and on the Advance Planning Committee recommendations on the future publication of the Handbook. All these things add up to a greater service to our membership — an area which we shall ever try to expand.

On February 12, our Senior Staff reported to Council on 1958 accomplishments, with a glimpse at future plans. Their reports were well illustrated, dramatically presented and received with high praise by Council. It would be impossible to reproduce here all they presented, but a few highlights from the presentations are of interest.

Ruby Redford, Editor:

"For instance, the nature of the material published during 1958. Ten years ago, a major editorial aim for the new magazine was 'Transactions Plus.' That is: retaining the valuable technical material the Society had always published—*plus* practical application articles on good current practice, staff-developed and staff-written, and also 'up-grading' material, papers and articles which might be neither strictly technical nor strictly application, but which anyone who qualifies as a member of IES should read whether he considers himself 'technical' or not.

"A breakdown will indicate our success in reaching objectives and the extent of staff-developed and staff-written material — for 1958."

Editorial Content — 1958

	Number of Titles	Number of Pages
Committee Reports	8	98
Technical Papers	27	242
Upgrading Material	28	152
Application Articles	77	161
° ° °		
Staff-Written Articles (included in above)	45	112
News (Staff-Written)	....	221

Clayton E. Ellis, Advertising and Promotion Manager:

"Some of you may recall that in 1948 when the Society's Officers decided to embark upon an enlarged publications program, soliciting advertising for ILLUMINATING ENGINEERING and expanding the size of IE for better display to text and to accommodate the advertising, they did so with some feelings of trepidation and uncertainty for the future. Having been a party to some of this early planning and action and, to some extent, these identical feelings, I cannot help but look back with gratification over these past ten years, as well may the Officers, Publications Committees and staff members who have been close to the operation. For by any standard of the publishing business or business in general, these ten years of operation have brought success to your publication and your Society, in improved service to the membership in general and other readers and as an advertising medium as well.

"It is readily apparent how much advertising has contributed to the total Publications program income over the past ten years, and should contribute for years to come. Largely through this income, particularly during the past few years, the Society has been able to make use of other funds for highly desirable expansion of other IES services to our members and has earned a surplus as well.

"The art and science of illumination and the Society have risen in stature considerably during the past ten years and your publication, ILLUMINATING ENGINEERING, has had no small part in this development."

C. L. Crouch, Technical Director:

A brief outline of how a technical committee report is developed will give

(Continued on page 23A)

They LOOK alike...

BUT...

A Stradivarius may look like an ordinary violin but we all know there is a great difference in performance. So it is with lighting standards. Two steel standards may look the same, but only Kerrigan standards have these plus values:

1. Superior strength, with stronger bracket connections
2. Heavier wall thickness (.130)
3. More resistance to bending—less deflection
4. Drop forged steel anchor base
5. 4 to 6 times greater resistance to corrosion
6. Guaranteed high yield point
7. One continuous longitudinal weld—Magnafluxed
8. Octagon shape—Inherently stronger than the round or fluted
9. Trim, modern lines, architecturally correct

NEW from KERRIGAN — THE CLASSIC Pat. Pending

Send for FREE catalogs on steel and aluminum standards—Address: Dep't. I-5

Weldforged LIGHTING STANDARD DIVISION

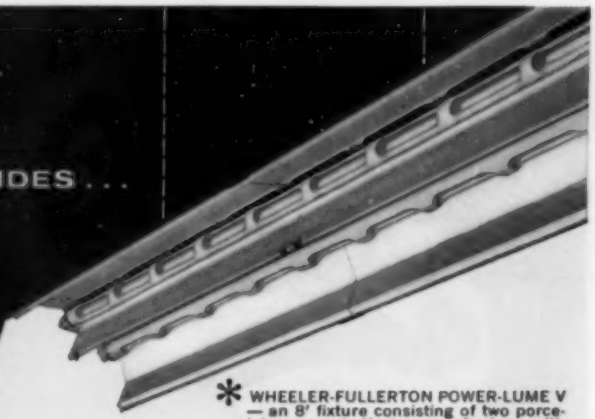
THE FORGES OF KERRIGAN

KERRIGAN IRON WORKS, INC.

Nashville, Tennessee

WHEELER-FULLERTON* PROVIDES . . .

LIGHT WITH A POWERFUL PLUS!



* WHEELER-FULLERTON POWER-LUME V — an 8' fixture consisting of two porcelain enamel 4' drawn reflectors with integral "V"; 27 shielding for highest efficiency, longest life and easiest maintenance.

A brighter, more efficient working area results with the installation of these outstanding Wheeler-Fullerton lighting fixtures. Here is light — but with a powerful plus! Designed for medium to high mounting applications, the Wheeler-Fullerton Power-Lume "V" delivers excellent control of light distribution, more comfortable seeing, cooler lamp operation PLUS twice the amount of lumen output per foot of lamp length.

Another PLUS — long life and diffuser aperture design for easy maintenance of reflecting surface.

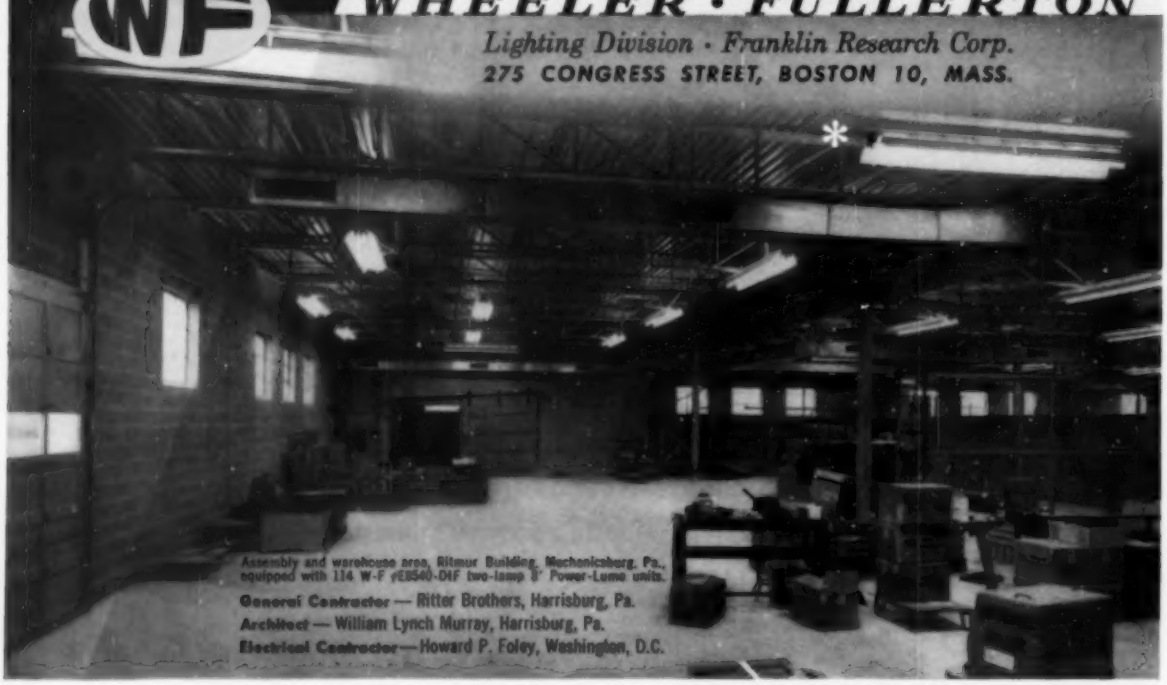
To solve your problems in lighting installation, write for complete information:

WF

WHEELER • FULLERTON

Lighting Division · Franklin Research Corp.

275 CONGRESS STREET, BOSTON 10, MASS.



Assembly and warehouse area, Ritmur Building, Mechanicsburg, Pa., equipped with 114 W-F #E8540-D1F two-lamp 8' Power-Lume units.

General Contractor — Ritter Brothers, Harrisburg, Pa.
Architect — William Lynch Murray, Harrisburg, Pa.
Electrical Contractor — Howard P. Foley, Washington, D.C.

(Continued from page 20A)

some idea of this aspect of the operations of the Technical Department.

Development Sequence	Technical Office Functions
President Advisory Board to President	Technical Director counsels as to needs and personnel.
Council establishes Committee	Negotiates and prepares list of chairmen and members for Council appointment.
Committee studies and drafts segments of reports	Presents background and objectives of work. Presents recent research and published data on work. Counsels on IES policy. Correlates with other committee work.
Committee develops final report	Reproduces drafts. Reviews drafts.
Technical Office	Reviews and edits final report. Reproduces report for Council. Letter of review to Council.
Council	Counsels.
Technical Office	Negotiates Council's comments, prepares manuscript. Prepares illustrations for publication.
Publications Office	Reviews galley proof.

Your Society is making real progress and we are proud to report the results to you.

GEORGE J. TAYLOR
President, 1958-1959

RQQ COMMITTEE, often called the "Ph.D.'s" of the Society, met at headquarters last month. Most of them Fellows of IES, clockwise around the table are: Willard Allphin, John Chorlton, E. M. Strong, President G. J. Taylor, John J. Neidhart, R. D. Bradley, Eric H. Church, S. K. Guth. In background is headquarters technical staff, John Kaufman and C. L. Crouch.

IT SEEMS TO ME

Planning Location Of Luminaires

I would like to comment upon the article "Planning Location of Luminaires" (March 1959 IE, page 137). Misunderstanding and misuse of the factor we call "mounting height" is the cause of poor light distribution and non-uniformity of illumination in otherwise well-designed lighting systems.

When the Lumen Method is used, the Room Ratio must be determined and here "mounting height" is the distance from bottom of fixture to floor for direct and semi-direct luminaires, or from ceiling to floor for semi-indirect and indirect luminaires, when the *Room Ratio table is used.* (Room Ratios are tabulated on the basis of the distance from the light source to the floor, with the work plane assumed to be 2 feet 6 inches above the floor.)

However, when the equation is used: Room Ratio $= W \times L/H\ (W + L)$, H is the distance from the light source (luminaire or ceiling) to the work plane. It is this mounting height "H" as used in the above equation that most manufacturers are using when they provide spacing-to-mounting height (S/MH) ratios for a luminaire.

Summarizing this, for the Room Ratio table, mounting height is the distance from luminaire or ceiling to the floor, but for using the Room Ratio equation or a manufacturer's S/MH factor, the mounting height is the distance from the luminaire or ceiling to the work plane. When the work plane is not 2 feet 6 inches above the floor, the equation must be used, to determine the Room Ratio. When the work plane is 2 feet 6 inches above the floor, the table may be used, but the designer must subtract 2 feet 6 inches from the mounting height above the floor to obtain the mounting height above the work plane to check against the manufacturer's S/MH factor.

In all the problems shown in this article, the mounting height used to check against the manufacturer's S/MH factors was the distance from luminaire to floor. In Problem II, luminaires are mounted 9 feet 6 inches above the floor. Assuming the work plane in this office as 2 feet 6 inches above the floor, the net mounting height is 7 feet above the work plane. Therefore, maximum spacing should not exceed 7 feet in either direction. The example in Problem II shows spacing of 7 feet 3 inches by 8 feet 8 inches, both exceeding 7 feet, and we would expect that the uniformity of illumination in this office is not as good as it would be if the job had been designed within the range of the manufacturer's factor, 1:1.

A similar error will be found in Problem I. Spacing should not exceed 7 feet for good design. In the other examples, the spacing does not exceed the S/MH when the true mounting heights are used, but the mounting heights used are wrong. If other problems were given with lower illumination levels, it is possible that all the problems would be incorrect. JULIUS KAYE, *District Manager and Engineer, New Jersey, Holophane Co., Inc., New York, N. Y.*

Reply to Discussion

In reply to Mr. Kaye's comments, the few problem examples were included merely to illustrate the article "Planning the Location of Luminaires."

In question is that part of each of four simple problems which states the mounting height of luminaires as specified by manufacturers' literature S/MH ratio. Mr. Kaye contends that most manufacturers in specifying S/MH mean spacing-to-mounting height on the work plane. Therefore, the problems used as a basis for illustrating luminaire spacing are incorrect. Mr. Kaye's assumptions are not in keeping with a recent check of manufacturers' catalogs. It is unfortunate that many manufacturers do not list S/MH ratios. However, a number of

(Continued on page 24A)

(*Continued from page* 23A)

manufacturers specify luminaire S/MH as meaning *spacing-to-mounting height above the floor.*

I was able to find only one manufacturer who listed S/MH as meaning, in their case, *spacing-to-mounting height above work plane.* Several other manufacturers include photographs showing luminaire *spacing-to-mounting height above floor as specific data.*

A recently published leading manufacturer's catalog lists the room ratio equation and its use. In the catalog every one of the manufacturer's many types of commercial and industrial lighting equipment (including control lens manufactured by the company Mr. Kaye represents) is specified with recommended *ratios of spacing-to-mounting height above the floor.*

The *IES Lighting Handbook*, Second Edition, pages 9-7 through 9-15, specifies MS, maximum spacing between units and MH, mounting height above floor. General diffuse luminaires, as illustrated on page 9-13, luminaires 37, 38 and 40, are typical of luminaires discussed in the article, "Planning the Location of Luminaires." Luminaire 37 shows (MS) a maximum spacing of 1.0 to 1.0 (MH) mounting height above the floor. Luminaire 38 has a MS of 1.0 to 1.0 MH above the floor. Luminaire 40 has a MS of 1.2 to 1.0 MH above the floor.

On page 9-17, paragraph quoted in part on luminaire spacing is as follows:

> "Table 9-2 gives the maximum permissible spacing for each luminaire distribution shown. These spacing limitations are related to the mounting height (above the floor) of direct, semi-direct, and general diffuse luminaires and to the ceiling height for indirect and semi-indirect systems. Observance of such limitations will ensure satisfactory uniformity of illumination throughout the room so that all parts of the area will be equally suitable for the intended use and spottiness and dark corners will be eliminated insofar as possible."

Fig. 9-1 supports further, by graphic definition, the proper spacing of luminaires as related to mounting height above the floor.

In a report of the IES Committee on Illumination Performance Recommendations (November 1954 IE, pages 552 and 553) a chart is published suggesting spacing-to-mounting height ratios on the basis of average candlepower distribution curves. Approximate maximum permissible spacing distances for direct, semi-direct and general diffusing luminaires based on flux ratios for direct (.825-.575) and semi-direct and general diffusing (.525-.325) luminaires are given.

Example: A semi-direct luminaire with a flux ratio of .475 mounted 10 feet above the floor or 7½ feet above the work plane has a spacing specified at 10 feet S/MH above the floor and is, therefore, on a 1:1 ratio for this luminaire distribution.

Example: A general diffuse luminaire with a flux ratio of .375 mounted 10 feet above the floor and 7½ feet above the work plane has a permissible spacing of 11 feet 6 inches, or in other words spacing to MH above floor is equal to a 1.1:1 ratio.

As it was established in the problems, it is first necessary to secure the manufacturer's S/MH ratio. If a manufacturer specifies the S/MH ratio to mean either the work plane or the floor it will affect only the total luminaires and not the four-step luminaire location method proposed.

In all illustrations of the lighting problems discussed in the article, which Mr. Kaye disputes, the spacing-to-mounting height ratios are under permissible maximum spacing ratios as they are defined in the *IES Lighting Handbook*, Second Edition.

There was no attempt made to establish or prescribe specifications for mounting heights of luminaires or levels of illumination in this article. Therefore, I do not understand Mr. Kaye's comment on this subject.

In the preface to luminaire spacing it was pointed out that prior to planning spacing six specifications must be determined: Level of illumination, system and luminaires, coefficient of utilization, maintenance factor, number of lamps and luminaires, and recommended spacing of selected luminaires. As previously mentioned, the problem begins after the number of luminaires has been determined.

The prime basis for the article was to discuss the following four-step method in planning location of luminaires when the total number of luminaires is determined.

(1) Establish distance from walls to first row of luminaires.

(2) Deduct both side wall rows of luminaires from total.

(3) Divide luminaires per row into balance remaining to determine number of rows.

(4) Divide number of rows into remaining width of the room after deducting total distance between outer rows and side walls. Always add one integral number of luminaire rows before dividing room width.

It is hoped this simple four-step method of planning location of luminaires will be of service to the less experienced as well as the experienced engineer.

JAMES F. FINN, *Coordinator, Commercial Sales Division, Detroit Edison Co., Detroit, Mich.*

I.E.S. National Technical Conferences

1959 — September 7-11 — Hotels Fairmont and Mark Hopkins, San Francisco, California

1960 — September 11-16 — Penn Sheraton Hotel, Pittsburgh, Pennsylvania

1961 — September 24-29 — Chase Park Plaza Hotel, St. Louis, Missouri

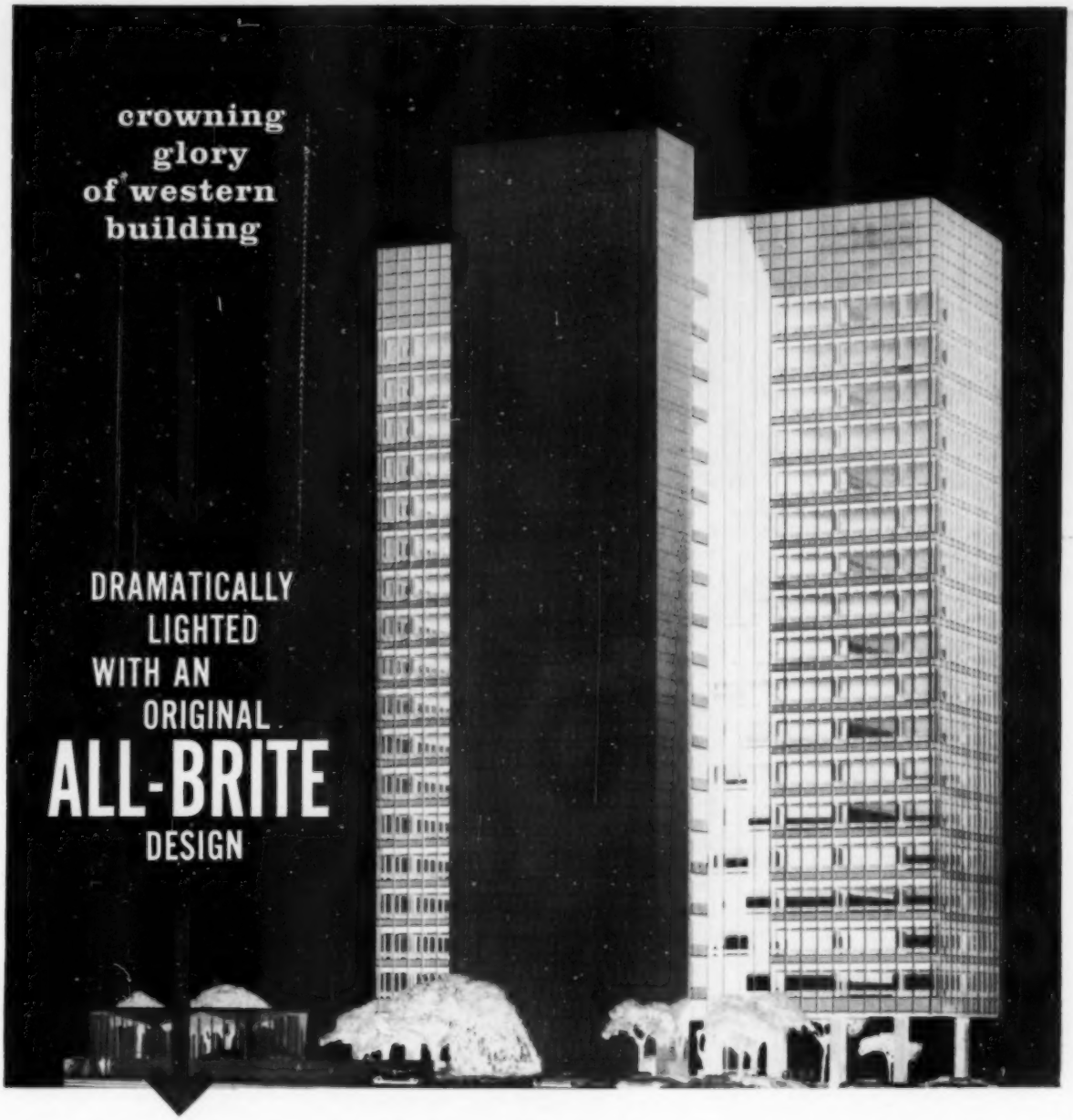
1962 — September 9-14 — Statler-Hilton Hotel, Dallas, Texas

1963 — — Sheraton-Cadillac Hotel, Detroit, Michigan

ABOUT PEOPLE

The Board of Directors of Westinghouse Electric Corp. has elected **Mark W. Cresap, Jr.** as president and chief executive officer of the company and **Gwilym A. Price** as chairman of the board. These elections coincided with an announcement by the University of Pittsburgh that Mr. Price had been elected president of the University's Board of Trustees. **E. V. Huggins,** vice-president and chairman of the executive committee and **John K. Hodnette,** executive vice-president, were re-elected to those positions. In addition, **Russell B. Read,** former assistant treasurer was named treasurer, serving under **George G.**

(*Continued on page* 26A)



NEW Crown Zellerbach Building, San Francisco

CREATIVE PARTICIPANTS

Architects: Hertzka and Knowles associated with Skidmore, Owings and Merrill, San Francisco.

General Contractor: Haas and Haynie, San Francisco.

Electrical Contractors: Ets-Hokin and Galvan associated with Chas. A. Langlais Co., San Francisco.

All-Brite

LIGHT OF AMERICAN COMMERCE

The new concept, unitizing light, heat and ventilation in one superb recessed fixture. Result: greatly simplified installation and convenient maintenance. Detailed information on request.

ALL-BRITE FLUORESCENT FIXTURES, INC.

352 SHAW ROAD, SOUTH SAN FRANCISCO, CALIF.

PLANTS ALSO IN LOS ANGELES AND SEATTLE
IN CANADA: ALL-BRITE LIGHTING (B.C.), VANCOUVER, B.C.
REPRESENTATIVES THROUGHOUT THE UNITED STATES AND CANADA

VIP's at the New York Section's April meeting were, left to right, IES President C. J. Taylor; Kurt Franck, Holophane Co., Inc.; Dr. H. Richard Blackwell; Section Chairman John W. Hamilton. Dr. Blackwell discussed "Research for Better Sight"; Mr. Franck tackled the problem of "Practical Meaning of High Footcandles." Meeting was held at the Consolidated Edison Auditorium in New York City.

(*Continued from page* 24A)

Main, vice-president, finance. Under revised company by-laws, Mr. Cresap has been assigned "general charge of the affairs of the corporation," and was designated "the officer through whom the Board delegates authority to corporate management."

F. W. Fulle has been named vice-president — sales of lighting products for Sylvania Electric (Canada) Ltd. During his twenty years with the company, Mr. Fulle has served in various managerial capacities, most recently as general sales manager.

E. O. Anders, Chairman of the Board, All-Brite Fluorescent Fixtures, Inc., San Francisco, and **John A. Wright,** president of Curtis Lighting, Inc., Chicago, have announced the formation of Curtis-Allbrite Lighting, Inc., with Mr. Anders serving as Chairman of the Board and president of the company. **Charles D. Buchanan** was named general sales manager of the combined organization and president of the Allbrite Division and Mr. Wright continues as head of the Curtis Division.

Revere Electric Manufacturing Co., Niles, Ill., has named **Russ Hedrick** to fill the newly-created position of production manager, with responsibilities for realignment of manufacturing and office methods to improve customer service. Prior to this appointment Mr. Hedrick was production superintendent for the company.

Sidney Sheldon has been elected vice-president — contract sales of Litecraft Manufacturing Corp., Passaic, N. J. Mr. Sheldon will be responsible for sales development, administration and coordination of the company's commercial sales division. He will continue to have his office at the company's New York City headquarters.

Crouse-Hinds Co. of Canada, Ltd. has announced the appointment of **Harry D. Rei** as general sales manager. Mr. Rei has been with the company for many years at the divisional management supervision level.

Hubbard and Co., Chicago, Ill., has announced the appointment of **L. T. (Don) Owen** as Mountain territory district sales manager. Mr. Owen will make his headquarters in Salt Lake City.

Keith S. Wood has been appointed Eastern District sales manager for the Canadian General Electric Co., with headquarters in Montreal, according to a recent announcement. Mr. Wood formerly served the company as a sales planning specialist in Toronto.

Warren Brennan has been named as sales representative for the state of New York by Moe Light Division of Thomas Industries, Inc., Louisville, Ky. Mr. Brennan's territory extends from Buffalo to Syracuse, north to Malone and south to Elmira.

Pfaff & Kendall, Newark, N. J., has announced the signing of two new sales representatives: **William Benndorf** Co. for the state of Arizona, and **James L. Wrathall** and **Leroy F. Kursi,** Wrathall & Kursi, Inc., for the San Francisco area.

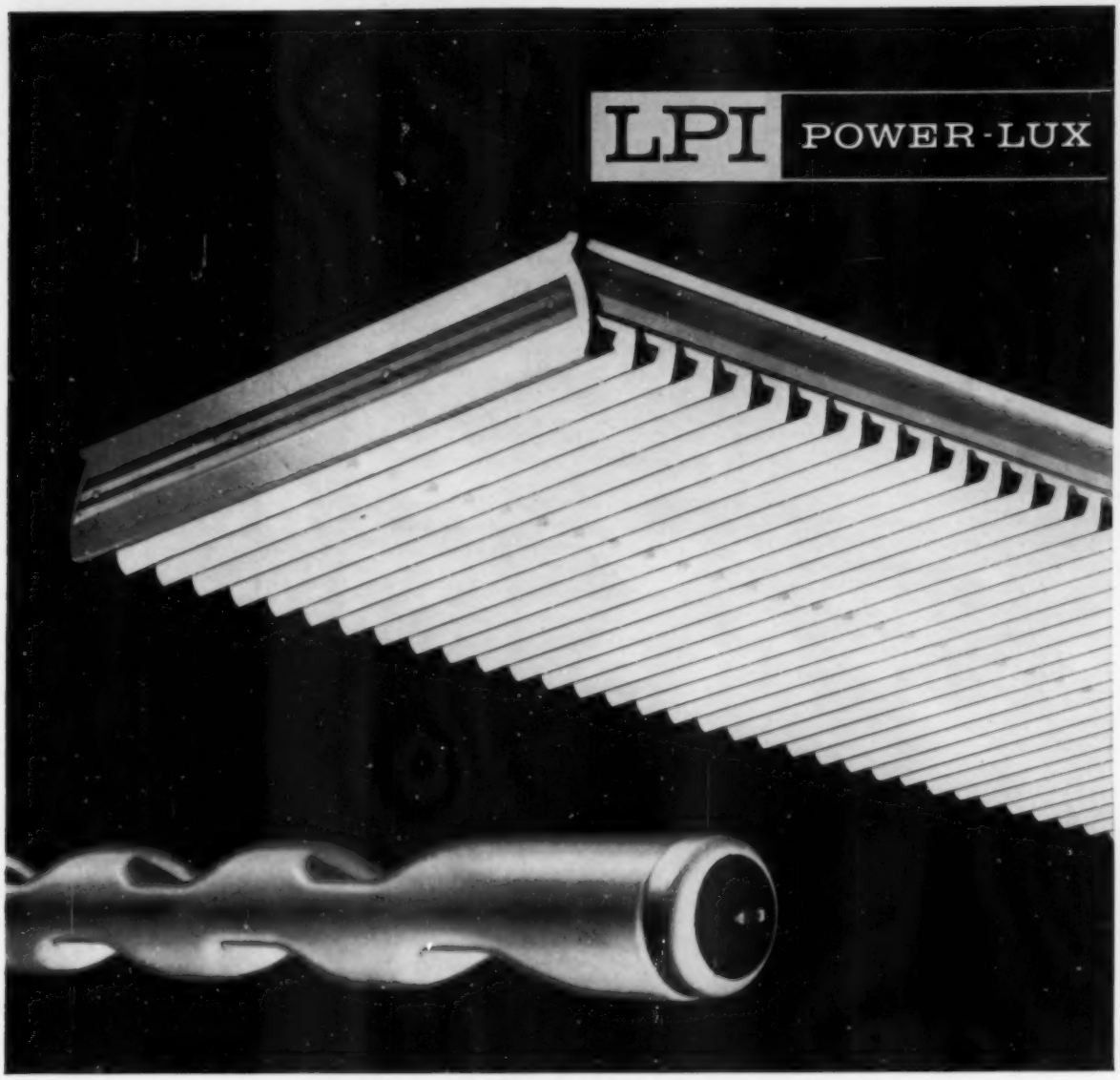
Samuel W. Charlesworth has been appointed Central Regional sales manager for Day-Brite Lighting, Inc., St. Louis, Mo. Mr. Charlesworth, who will be directly responsible for field sales personnel in the Region, is moving to St. Louis from his former post with the General Electric Supply Co. in Baltimore. Also announced by Day-Brite was the appointment of **Harold M. Horton** as sales associate in the Atlanta territory of **Oren M. Ruff, Jr.** and **Cecil L. Cannon.** Mr. Horton has been in the lighting industry for 33 years, having spent 29 of them as a district lighting engineer for General Electric Lamp Division in Atlanta, Ga.

Garlan Morse, Vice-President in charge of sales, Sylvania Lighting Products has announced the appointments of **Leslie E. Innis** as manager — equipment manufacturer sales and **Joseph M. Root** as sales supervisor in the Philadelphia district. Mr. Innis, who has been with Sylvania since 1951, served as a commercial engineer—incandescent lamps, and most recently as district lamp engineer in Chicago. In his new position, he will work with manufacturers of equipment using special lighting, such as appliances and office copying machines. Mr. Root, who will head the company's sales force in the northern and western Philadelphia district has served as a sales representative in that district since joining Sylvania in 1950. A third Sylvania appointment is that of **Lawrence A. Smith** as sales promotion manager. Mr. Smith was formerly in the advertising and sales promotion department of General Electric Co. in New York and Nela Park.

Effective April 1, 1959, the official corporate name of **Smithcraft** Lighting, Chelsea, Mass. became Smithcraft Corp., as the 60-year-old corporate name, A. L. Smith Iron Co. was discarded. Corporate ownership and management remain the same.

Wilfred Henschel has announced his resignation from the engineering department of the Port of New York Authority and his availability for consulting and design services on electrical installations.

(*News continued on page* 28A)



60,000 lumens at 80-percent efficiency

LPI Power-Lux luminaire gives stores over 200 footcandles with Power Groove lamps, is engineered for comfortable brightness

A specially designed luminaire now lets you light stores with improved Power Groove lamps. Manufactured by Lighting Products Inc., Power-Lux incorporates special engineering features which provide 80-percent efficiency. Exclusive parabolic louvres control 60,000-lumen output of four Power Groove lamps, providing high-level illumination at comfortable brightness.

One economical Power-Lux with Power Groove lamps does the job of three ordinary slimline fixtures.

Power-Lux is an outstanding choice for new stores as well as for raising lighting levels of existing commercial buildings. In re-lighting applications, the new luminaire simply replaces present fixtures to give dramatic increases in illumination.

Power-Lux is available in four-lamp models, 36 inches wide; and in two-lamp models, 12 inches wide. Both are supplied in four and eight-foot lengths. **For complete information write for LPI's Power-Lux Bulletin.**

Lighting Products Inc. Highland Park, Illinois

LPI FLUORESCENT LIGHTING

(*News continued from page* 26A)

BOOKS AND PAMPHLETS

Heating, Ventilating, Air-Conditioning Guide, 1959, 37th Edition, published by American Society of Heating, Refrigerating and Air-Conditioning Engineers, 768 pp. Price: $12.00 per single copy.

Enlarged to 8½" x 11" page size, the 1959 Edition of this annual publication follows the format of previous editions and is divided into 12 sections: Fundamentals; Environment, Comfort and Physiological Principles; Heating and Cooling Loads; Room Heating and Cooling Methods and Equipment; Air Systems and Equipment; Steam and Water Systems and Equipment; Heat Generating Methods and Equipment; Refrigeration, Spray Apparatus and Sorbents; Controls, Instruments and Motors; Specific Applications; Industrial Systems and General. Five new chapters cover High Temperature Water Systems, The Heat Pump, Evaporative Air Cooling and Humidification and Snow Melting. In addition to the Technical Data Section, the Guide also includes a Catalog Data Section, featuring the latest heating, ventilating and air-conditioning equipment.

Summary of Economic Aspects of Single Complete Electric Service Compared with Dual Electric and Gas Service for Multiple Housing, published by Edison Electric Institute, 750 Third Ave., New York 17, N. Y., 16 pp. Price: $1.00 per single copy, discounts on orders of 100 or more.

A digest of the recently-published "Gilbert Report," this booklet summarizes, in non-technical terms, the facts to be considered in the selection of all-electric service or combination electric and gas service for multiple housing of the type often used on military installations. Data and analysis standards are provided to facilitate economic comparisons of the two types of service.

Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy, National Electrical Manufacturers Association Publication WC 3-1959. Price: $4.00.

Approved by both the Insulated Power Cable Engineers Association and NEMA, this publication gives detailed information on conductors, insulation, shielding and coverings; cabling, fillers, binders and circuit identification; testing and test methods; pole and bracket cable, non-metallic neoprene-jacketed power cables, pre-assembled aerial cable using copper conductors and neutral-supported secondary and service drop cables.

Your First Five Years; Selected Reading for Young Engineers, Personal Appraisal, published by Engineers Council for Professional Development, 29 West 39th St., New York, N. Y. Prices: 10 cents, 15 cents, 10 cents, respectively.

Three new pamphlets published as part of the Council's "First Five Years" program, are designed to guide the young engineer toward advancement in the early years of his career. The publications are available separately or can be obtained with the purchase of the Council's basic reference manual, *A Professional Guide for Young Engineers.* Cost of the *Guide*, including the three pamphlets, is $1.00.

Color Coding of Wires and Cables, National Electrical Manufacturers Association Publication WC-1959. Price: 30 cents.

This booklet covers the color coding of asbestos, asbestos-varnished cloth and asbestos-thermoplastic insulated wires and cables; textile coverings for flexible cords and POSJ flexible cords, rubber-insulated wires and cables.

NEW MEMBERS

At the meeting of the I.E.S. Council Executive Committee on April 22, 1959, the following were elected to membership. Names marked * are transfers from Associate Member Grade. Names marked ** are transfers from Student Member Grade.

ALABAMA SECTION

Members:
*Davidson, Samuel, Alabama Power Co., Montgomery, Ala.
*Hazzard, M. R., Hazzard, McRoy & Cone, Birmingham, Ala.
Associate Member:
Brown, H. W., Jr., Spurgeon-Brown, Birmingham, Ala.

ALAMO SECTION

Associate Member:
Baker, G. M., 342 W. Woodlawn, San Antonio, Texas.

ARIZONA SECTION

Associate Members:
Dankowski, Leonard, Arizona Public Service Co., Buckeye, Ariz.
Hansen, C. A., Westinghouse Electric Supply Co., Phoenix, Ariz.
Miller, H. M., Arizona Public Service Co., Phoenix, Ariz.
Morgan, Bruce, Westinghouse Electric Supply Co., Phoenix, Ariz.
Stevens, H. H., Tri-State Associates, Glendale, Ariz.
Wood, F. B., Westinghouse Electric Corp., Scottdale, Ariz.
Zimel, Jack, Regal Lighting Fixture Co., Phoenix, Ariz.

BLUENOSE CHAPTER

Member:
*Myra, D. C., Maritime Telegraph & Telephone Co., Ltd., Halifax, N. S.
Associate Members:
Flynn, A. A., Marlite Co., Ltd., Halifax, N. S.
Flynn, A. P., Corp. of City of Halifax, Halifax, N. S.
Howell, J. B., Federal Pacific Electric Co., Halifax, N. S.
Zinck, A. B., Harris & Roome, Ltd., Halifax, N. S.

BRITISH COLUMBIA SECTION

Associate Members:
Cowan, J. M., B. C. Fluorescent Sales & Service, Ltd., Vancouver, B. C.
Harshaw, F. N., Crouse-Hinds Co. of Canada, Ltd., W. Vancouver, B. C.
Melton, H., Black Brothers, Ltd., Vancouver, B. C.
Mohler, Norman, Rainbow Lighting Co., Ltd., Vancouver, B. C.
Solby, A. C., Ideal Electric, Ltd., Vancouver, B. C.
Stewart, A. J., Swan & Wooster Engineering Co., Ltd., Vancouver, B. C.

CAPITAL SECTION

Member:
Reno, E. A., U. S. Coast Guard, Civil Engineering Division, Signal Branch, Washington, D. C.
Associate Members:
Friedman, M. M., Star Electrical Contracting Co., Washington, D. C.
Sullivan, C. B., Department of Highways and Traffic, Washington, D. C.

CENTRAL FLORIDA CHAPTER

Associate Members:
Thrasher, D. E., Florida Power & Light Co., Sanford, Fla.
Ward, W. D., Florida Power Corp., Deland, Fla.

CENTRAL ILLINOIS CHAPTER

Associate Members:
Klein, R. L., Crescent Electric Supply Co., Peoria, Ill.
Smith, S. W., Beling Engineering Consultants, Peoria, Ill.

CHICAGO SECTION

Members:
*Gand, R. C., Benjamin Electric Mfg. Co., Des Plaines, Ill.
Schmals, H. L., Nicol & Nicol, Chicago, Ill.
Associate Members:
Berg, L. R., General Electric Co., Chicago, Ill.
Joyner, E. A., Steber Mfg. Co., Broadview, Ill.
O'Connell, J. A., Luminous Ceilings, Inc., Chicago, Ill.
Williams, R. A., Pittsburgh Reflector Co., Chicago, Ill.
Wilson, P. R., Forest City Electric Supply Co., Rockford, Ill.

CHINOOK CHAPTER

Associate Members:
Cloutier, C. O., 320 21st Ave., S. W., Calgary, Alta.
Eades, T. E., Eades Electric, Ltd., Calgary, Alta.
Hovdebo, J., Canadian General Electric Co., Calgary, Alta.
Miller, R. L., Miller Electric, Calgary, Alta.

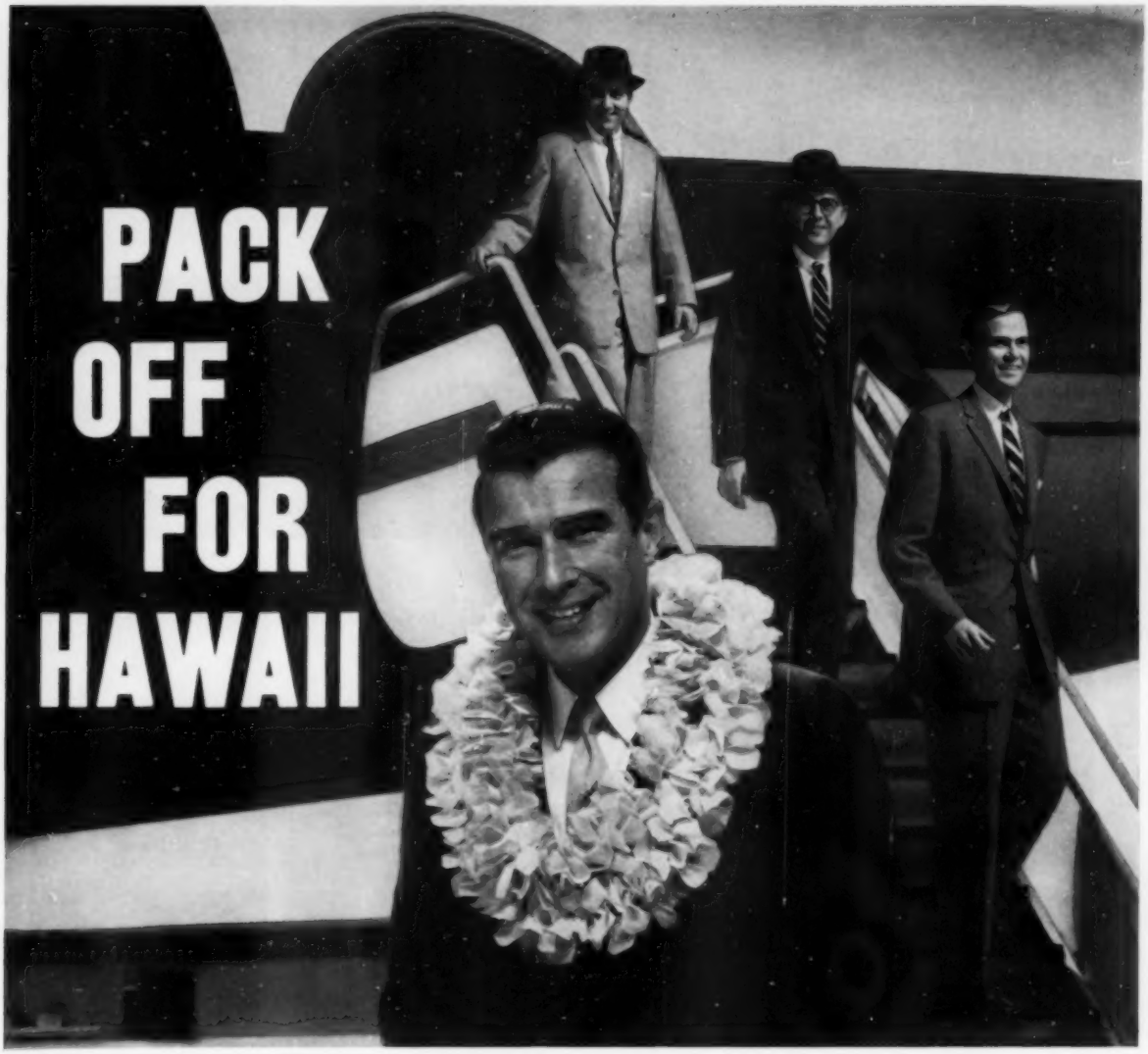
CLEVELAND SECTION

Members:
*Johnson, W. H., Westinghouse Electric Corp., Cleveland, Ohio.
Maro, J. J., Jr., The Osborn Engineering Co., Cleveland, Ohio.
*Sternberg, Lewis S., Midland Electric Co., Cleveland, Ohio.

CONNECTICUT SECTION

Associate Members:
Broska, A. F., Fletcher, Thompson, Inc., Bridgeport, Conn.
Cunningham, H. G., Technical Electric Sales Associates, W. Hartford, Conn.

(*Continued on page* 39A)



...after the Convention

Everybody expects a hard-working convention this year, so when it's all over come fly with us on a post-convention tour to Hawaii . . . just a state away . . . prepared especially for you by American Express.

Leave San Francisco September 12, 1959. Stay at the Royal Hawaiian. Visit Waikiki Beach . . . Diamond Head . . . Koko Head Crater . . . Pearl Harbor . . . Nuuanu Pali . . . the island of Oahu.

Enjoy a lively post-convention meeting and such thrilling entertainment as dinner and floor show at the beautiful new Princess Kaiulani Hotel.

Also available: 2 and 3-week extension tours to the Garden Isle of Kauai . . . and Maui.

All-expense, escorted from $585 to $1,110.

Make your reservations now through your Travel Agent or

AMERICAN EXPRESS
TRAVEL SERVICE

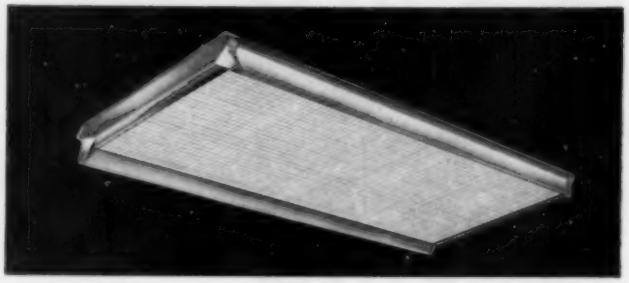
Head Office:
65 Broadway, New York 6 • WHitehall 4-2000
For the address of your nearest American Express office, call Western Union Operator Number 25.

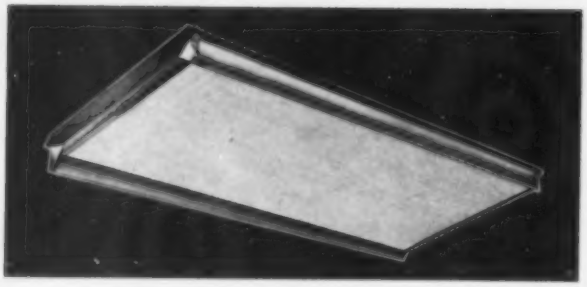
PROTECT YOUR TRAVEL FUNDS WITH **AMERICAN EXPRESS TRAVELERS CHEQUES**—SPENDABLE EVERYWHERE

APPLY NOW FOR YOUR AMERICAN EXPRESS WORLD-WIDE CREDIT CARD

For Architecture and Sculpture in lighting specify the –

SCULPTURAMA
THE SCULPTURED LOOK IN LIGHTING



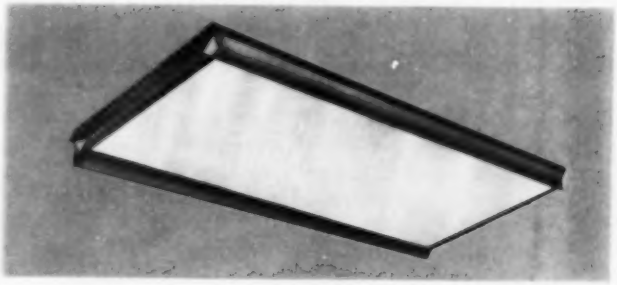


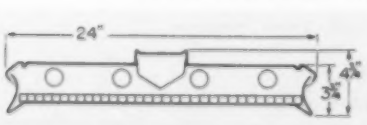
QPLM7500 with miniature-celled plastic louver shielding

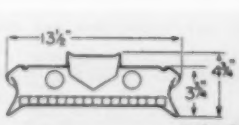
QPCX7500 with SUNLUX; *clear optically sharp plastic lens panel*

QCA7500 with translucent white Albalite glass diffuser

SCULPTURAMA, the Sunbeam Lighting Company's #7500 series Visionaire®, has the refinement in design and the sculptured look which fuses itself with today's architecture. Shallow in appearance, it forms a surface mounted, "area" source of pleasant, low-brightness illumination. All-metal sides are gently curved and are illuminated with interflected light to reduce fixture-to-ceiling contrasts. The sturdily framed single-element diffuser opens from either side on continuous "hook-on" hinges and may be completely removed without use of tools. For maximum versatility, SCULPTURAMA is available in a wide range of diffusing mediums, including SUNLUX, for 2 or 4 rapid start lamps and for single or continuous row installation. Write for bulletin #A84c







patents pending

visionaire

SUNBEAM LIGHTING COMPANY LOS ANGELES, CALIFORNIA GARY, INDIANA

Cut your fluorescent lighting investment as much as 40¢ per square foot —with new General Electric Power Groove Lamps!

- Power Groove gives lowest cost of fluorescent light for most users...
- Saves 10-30% on initial investment, alone...
- Stays cleaner, brighter longer—cuts end darkening
- Will last about 3 years in single-shift service

INITIAL INVESTMENT REDUCED—*You can save up to $4,000 on every 10,000 square feet of lighted floor area* by specifying new General Electric Power Grooves over other types of fluorescent lamps. This is based on a typical industrial area and a practical 100 footcandle lighting level which will help you get increased production through higher worker efficiency and comfort.

HOW? Use new G-E Power Grooves, the most powerful fluorescent you can buy. If you're in the midst of planning a new building, or remodeling an existing one, you'll welcome the sizeable savings in capital investment. For a given lighting level, you need fewer G-E Power Groove Lamps, fewer fixtures . . . less installation time.

COMPARE POWER GROOVE COSTS: Using average conditions, figuring the cost of the lamps, fixtures, distribution equipment and labor, here's a cost comparison of the major types of fluorescents:

YOU CAN SAVE THIS MUCH ON INITIAL INVESTMENT BY USING 8-FOOT G-E POWER GROOVE LAMPS

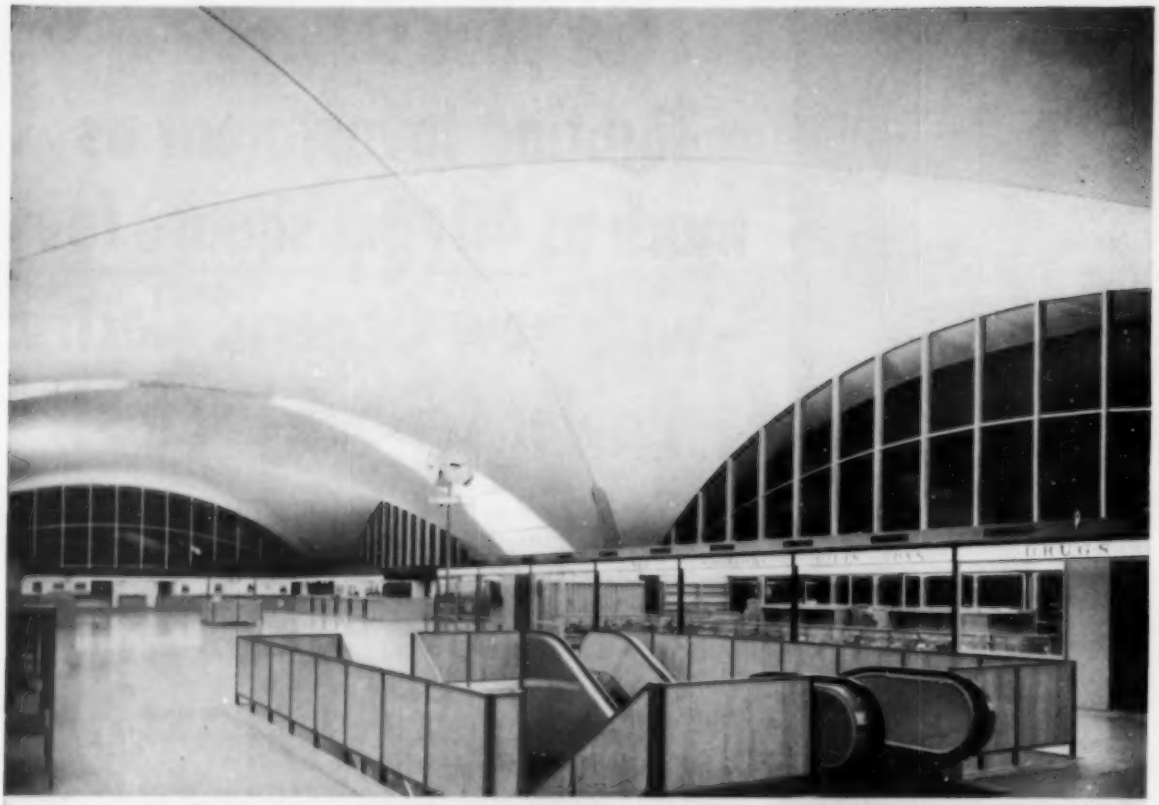
(Based on a desirable 100 footcandle level, at about 95¢ per square foot using Power Grooves)

	YOUR SAVINGS PER FOOT	YOUR SAVINGS PER 10,000 FT.
POWER GROOVES vs. 4′ 40-WATT RAPID START (at $1.35/sq. ft.)	40¢	$4,000
POWER GROOVES vs. 8′ SLIMLINE LAMPS (at $1.35/sq. ft.)	40¢	$4,000
POWER GROOVES vs. 8′ HIGH OUTPUT LAMPS (at $1.15/sq. ft.)	20¢	$2,000

NEW G-E POWER GROOVES come in 4, 6, and 8-foot lengths—and all have the new G-E cathode shield that keeps ends brighter longer. This collects the tiny electrode particles that would otherwise be deposited on the tube wall. These lamps are interchangeable with original Power Grooves—yet they sell for the same price! For more information, write: General Electric Co., Large Lamp Dept. C-920, Nela Park, Cleveland 12, Ohio.

Progress Is Our Most Important Product

GENERAL ELECTRIC



St. Louis Municipal Airport Terminal Building

•

Hellmuth, Yamasaki & Leinweber, Architects
Ferris & Hamig, Electrical Engineers
Roberts & Schaefer, Dome Consultants

•

• 110KW in color corrected mercury lamps, neatly concealed, produce this masterpiece of comfortable indirect light. Not an installation in America like it!...There are 100 Rambusch Field Representatives. One of them is near you and anxious to serve.

RAMBUSCH **DESIGNERS • MANUFACTURERS**
40 WEST 13th STREET, NEW YORK 11, N. Y.

Why Lustrex* Perma Tone Styrene for "creative" ceilings?

First, of course, for the obvious advantages of styrene in lighting: large areas of illumination possible, lightweight, good diffusion, and the unlimited color possibilities. But why perma tone? For improved color stability under ultra violet light. For 2 to 3 times more resistance to yellowing, assuring truly translucent whites and a wide range of colors.

Write for Bulletin #2491 on Lustrex perma tone specially developed to meet IES—NEMA—SPI joint specifications for ultra violet light stabilized styrene. Monsanto Chemical Company, Plastics Division, Room 1317, Springfield 2, Massachusetts.

Monsanto

*LUSTREX: REG. U. S. PAT. OFF.

LUMENAREA Ceiling System in First National Bank, Omaha, Nebraska. Santay Corporation of Chicago molds the Lustrex louvers for these ceilings manufactured by Electro Lighting Corp., Chicago. Architect: John Latenser & Sons; Contractor: National Electric Co., Inc.; Distributor: General Electric Supply Co.

The recently-built plant of the New Era Mfg. Co., which specializes in multi-color flat-bed letterpress, prints any number of colors and completes in one operation all types of labels, tags, IBM and Remington Rand Punch Cards.

THE BEST BUY IN SIGHT — FIXTURES USING EXTRU-LITE®

ROTUBA'S PRISMATIC PLASTIC LENS *Plus* SYLVANIA'S FIXTURES

achieve new goals in quality lighting

The low 8 ft. ceiling of the President's luxurious office in the ultra-modern New Era Manufacturing plant, Hawthorne, N. J., strongly suggested the use of a shallow, close-to-the-ceiling fixture.

For luminosity as well as decor, several rows of **Sylvania's new rectangular Mohawk Fixture** were installed. See how attractively this slim luminous beam hugs the ceiling and follows the design pattern of the grid ceiling system and motif of the wood wall-paneling.

Extru-Lite*, the plastic shielding featured in this fixture, diffuses the light evenly and well, giving superior distribution with low brightness. The result is a soft, easy-on-the-eyes illumination. Architecturally and visually the perfect lighting solution for this room.

Throughout the plant, SYLVANIA'S lighting corresponds to the same high standards as in the chief executive's office.

Sylvania Troffers with Extru-Lite score with "pin-point illumination" at Warren Bowl, Warren, Ohio, the modern, well-lit bowling alley.

SYLVANIA'S new recessed Troffers light a bowling alley effectively. One major advantage of using this Troffer paneled with Rotuba's prismatic plastic:— Extru-Lite affords the best benefits of high level illumination without blanketing the entire ceiling with lighting fixtures or luminous ceilings. The "pin-point illumination" that results is shadowless and glare-free putting no strain on the bowler's or spectator's eyes.

* Available in both Polystyrene or Acrylic.

THE ROTUBA EXTRUDERS, INC.

A DIVISION OF WALJOHN PLASTICS, Inc.

MAKERS OF PLASTIC EXTRUSIONS FOR INDUSTRY

437 88th STREET, BROOKLYN 9, NEW YORK • SHORE ROAD 8-5458

RIGID PLASTIC EXTRUSIONS

problem

High-foot-candle levels from recessed fixtures were required for Pereira & Luckman's contemporary design of the new IBM Western Headquarters Building.

solution

The ARGUS LUMINAIRE was designed by Lighting Dynamics. Now in production, it is the first recessed troffer using high output and very high output lamps supplying high-footcandle levels to critical seeing areas in drafting, engineering rooms, laboratories, banks, and offices. ARGUS' clean contemporary lines produce EXCITING ARCHITECTURAL EFFECTS with long parallel strips of unbroken light. This new series comes in a WIDE VARIETY OF WIDTHS AND LENGTHS that completely integrate with ceiling materials. Easy to install. As with all Lighting Dynamic luminaires, the Argus features durable, Bonderized and electrostatic, high-reflectance finishes. FOR MORE COMPLETE INFORMATION fill out the coupon below and mail to Lighting Dynamics, 802 West Whittier Boulevard, Whittier, California; or to Lighting Dynamics, 8700 Ambassador Row, Dallas, Texas.

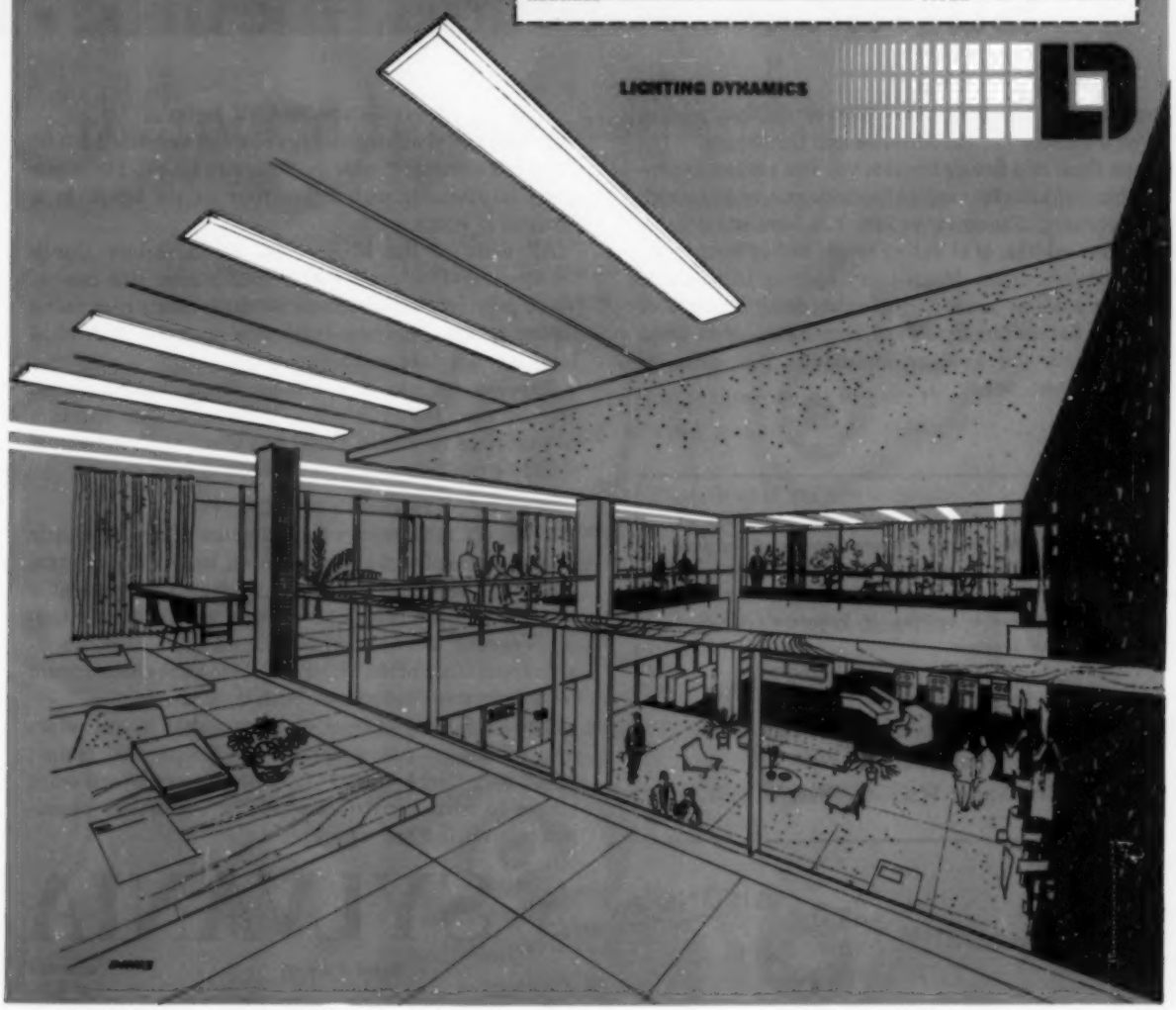
_____ *Send more information on* ARGUS.

_____ *Send your new catalog.*

NAME _____ PHONE _____

ADDRESS _____ TITLE _____

LIGHTING DYNAMICS



ARGUS as it will be used in the IBM Western Headquarters Building designed by Pereira & Luckman.

go modern with a Sylvania Surface Mounted Fixture

Sylvania offers *two* attractive series of shallow, surface mounted fixtures . . . the *Mohawk* and the *Seneca.*

From these two fixture families you can choose appropriate lighting units for modern low ceilings . . . and to match the proportions of almost any room. You have an extensive selection of widths, of shielding media and of lamp types to practically custom-design every lighting installation.

Take a look at some of the outstanding features of these two fixture families. Then keep Sylvania in mind the next time you have an installation that calls for surface mounted units.

These two fixture series typify the broadness of Sylvania's entire line of modern fluorescent lighting equipment. To bring yourself up to date on the most complete fluorescent fixture line in the industry, write today for a catalog of Sylvania's Lighting Fixtures and Systems.

SYLVANIA LIGHTING PRODUCTS
A Division of SYLVANIA ELECTRIC PRODUCTS INC.
Department 59-5
One 48th Street, Wheeling, West Virginia

Sylvania's MOHAWK Series

This series of shallow fixtures comes in two widths. The *Chief* is a nominal 1′ wide and uses two lamps. The *Super Chief* is available with either four or six lamps in a nominal 2′ width.

All units of the MOHAWK Series feature sturdy "wrap-around" chassis with ribbed plastic side panels. These polystyrene side panels illuminate the surrounding ceiling area to minimize brightness contrasts with ideal blending of fixture and ceiling.

Through the use of a smooth fitting, hidden-hinged shield frame, the MOHAWK provides a wide selection of shieldings in plastic, metal and glass, to fit individual shielding preferences.

Sylvania's SENECA Series

The SENECA features a dished panel of acrylic plastic which fastens directly to the fixture body without extra supporting devices. The resulting clean lines present a smart appearance which harmonizes with modern interiors. Together with soft, diffused illumination, the fashionable appearance of the SENECA makes it the ideal fixture for many stores and offices, both large and small.

The availability of three different widths in this versatile, solid-sided fixture series—13⅜″ with two lamps; 15⅛″ with four lamps; 23¾″ with six lamps—makes it simple to select the fixture width for the desired illumination level and room appearance.

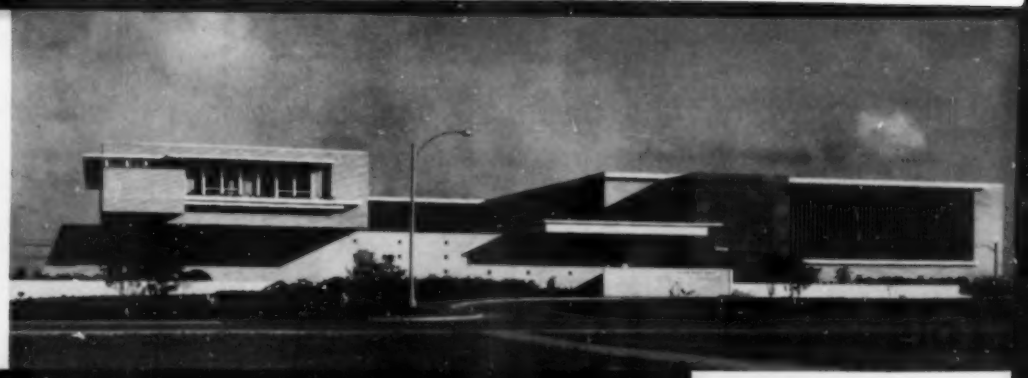
GO MODERN WITH LIGHTING BY **SYLVANIA**

Subsidiary of
GENERAL TELEPHONE & ELECTRONICS

GENERAL SYSTEM

FLUORESCENT LIGHTING FIXTURES AND SYSTEMS • BEST FIXTURE VALUE IN EVERY PRICE RANGE

Decorative and security lighting for the Administration Center of Dow Chemical Company's Texas Division is achieved through use of 15 Wide-Lites placed around the building.



Wide-Lite Model F-400-AWB

creative lighting calls for **WIDE-LITE**

Dramatic lighting effects are easily achieved when Wide-Lites are selected as the lighting engineer's basic tool.

Designed especially to enhance the unique characteristics of color-corrected mercury vapor lamps, Wide-Lites bring *new dimension* to decorative lighting. They produce broad patterns which may be overlapped to provide smooth, even coverage without concentric circles, hot spots, or dark shadows to mar the architectural harmony of a building. The patterns are unusually uniform and may be accurately plotted to determine the exact number of units needed to provide any desired illumination level.

Ruggedly constructed from cast aluminum alloy, Wide-Lites are finished in aluminum epoxy paint for corrosion control. All outdoor models are sealed with tempered glass lenses, and relamping is accomplished without disturbing the seal of the lens. Exclusive built-in heat radiating fins limit lamp temperatures to the most efficient range. Sizes range from 100-watt to 1000-watt, and a choice of reflectors is available on all models.

To assist you in planning dramatic decorative lighting effects, Wide-Lite engineers have prepared a unique group of transparencies which read directly in Wide-Lite beam footcandles. Write today for your set . . . and a copy of Catalog 444 which gives information on the complete Wide-Lite line of indoor, outdoor and special application fixtures.

WIDE-LITE

Manufactured by

WIDE-LITE CORP.

P. O. Box 191 • Houston 1, Texas

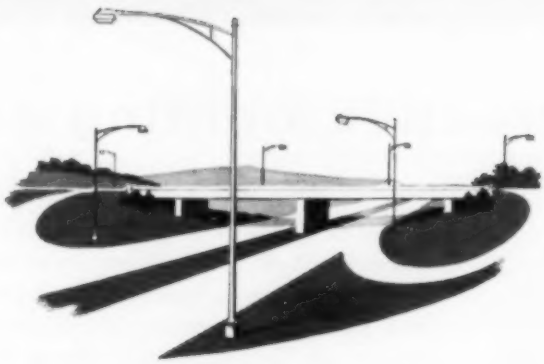
IN CANADA: WIDE-LITE DIVISION OF WAKEFIELD LIGHTING, LIMITED • LONDON, CANADA

for street lighting • highway lighting • floodlighting

UNION METAL MONOTUBE POLES

Monotube street lighting poles . . . steel or aluminum . . . round or fluted . . . davit or bracket styling . . . anchor or transformer base. Attractive in any location. Continuous-tapered Monotube poles are available in a broad range of designs and sizes to meet all requirements.

Monotube highway lighting poles are offered for various mounting heights and strength requirements. Easily wired and installed. Steel Monotubes are made from high grade, open hearth steel and cold-rolled for strength. Aluminum poles are made by the spinning method.



Monotube floodlighting poles . . . for sports, business, industrial or recreational areas. Available in heights from 20 to 100 feet. Monotube designs permit extreme flexibility in arrangement and number of light units per pole. Floodlights can be mounted, positioned and wired while pole is on the ground.

THE **UNION METAL** MANUFACTURING COMPANY

CANTON 5, OHIO — BRAMPTON, ONTARIO, CANADA

Monotube Lighting Poles

(Continued from page 28A)

Olschan, Robert, The Olschan Electrical Supply Co., Bridgeport, Conn.

CORNHUSKER SECTION

Member:
*Knudson, E. C., Leo A. Daly Co., Omaha, Nebr.
Associate Member:
Dunleavy, D. R., Leo A. Daly Co., Omaha, Nebr.

EASTERN NEW YORK SECTION

Associate Members:
Barhydt, W. R., Tusang-Barhydt, Inc., Albany, N. Y.
White, R. A., Sylvania Lighting Products, Inc., Latham, N. Y.

EASTERN PENNSYLVANIA SECTION

Associate Members:
Crosby, G. E., Radio Corp. of America, Lancaster, Pa.
Estricher, H. A., Modjeski and Masters, Consulting Engineers, Harrisburg, Pa.
Funke, O. J., Funke Neon Tubes, Lancaster, Pa.
Raymond, William, 3 Ivory Rock Rd., Levittown, Pa.

EDMONTON CHAPTER

Associate Members:
Downey, Gerry, Northland Utilities, Ltd., Edmonton, Alta.
Nairn, K. E., Canadian Comstock Co., Ltd., Edmonton, Alta.

FLORIDA SECTION

Members:
MacCartney, L. F., Jr., Florida Power Corp., St. Petersburg, Fla.
*Sanders, J. B., Tampa Electric Co., Tampa, Fla.
Wilfong, W. H., Florida Power Corp., St. Petersburg, Fla.
Associate Members:
Dukes, R. E., Brockman Electric Supply, Inc., Sarasota, Fla.
Parker, D. H., Roy A. Parker, Electrical Contractor, Bradenton, Fla.

FOREIGN NON-SECTION

Members:
Pickup, J. F., Dept. of Electrical Engineering and Physics, The Borough Polytechnic, London S.E.1, England.
Williams, R. C. G., Philips Electrical Ltd., Century House, Shaftesbury Ave., London W.C.2, England.
Associate Members:
Crome, A. T., Australian Electrical Industries Pty. Ltd., Melbourne, Victoria, Australia.
Pinto, Ruben, Cia Minera Santa Fe (3er Piso) Augustinas 1161, Santiago, Chile.
Vasta, Francesco, Via Del Gambero 8, Rome, Italy.

FOREST CITY CHAPTER

Member:
Howley, J. T., Giffels & Vallet of Canada, Ltd., Windsor, Ont.

GEORGIA SECTION

Member:
*Koen, J. H., Georgia Power Co., Atlanta, Ga.
Associate Members:
Lykins, G. E., General Electric Supply Co., Atlanta, Ga.
Smith, H. A., Jr., Georgia Power Co., Gainesville, Ga.
Stroh, K. R., Noland Co., Inc., Atlanta, Ga.

GOLDEN GATE SECTION

Associate Member:
Hubbard, W. A., Republic Electric Co., San Francisco, Calif.
Student Member:
Brown, G. L., University of California, Berkeley, Calif.

HEART OF AMERICA SECTION

Member:
Mann, R. E., Mann & Co., Hutchinson, Kans.
Associate Members:
Gillespie, K. G., 1268 W. 61st Terrace, Kansas City, Mo.

(Continued on page 40A)

SEEMORE SAYS: LOOK! NEW!
Guth brascolite
GYM LIGHTS
You relamp 'em without ladders
FROM ABOVE
OR BELOW
From above, just snap-out the reflector. From below, use a relamping stick. No sky-high ladders to mess with!
They're available with hinged wire guard and 40° shielding louver —and with louver or guard only. Both pendant and recessed units are listed by Underwriters Laboratories, Inc.
High quality 60° beam ALZAK reflector for high efficiency, easy maintenance, long life.
THERE ARE MANY MORE GUTH GYM LIGHTS TAKE YOUR PICK:
Single, double, triple and quadruple units, for high or low bay installations, 100% downlight or with 15% uplight, round or square, pendant or recessed.
WRITE FOR GYM LIGHTING DATA SHEETS TODAY!
Guth
THE EDWIN F. GUTH CO.
St. Louis 3, Mo.
TRUSTED NAME IN LIGHTING SINCE 1902

PANS MADE WITH FROST-WHITE-X SHEET ARE BREAK-RESISTANT, REFLECTION-FREE AND GUARANTEED LIGHT STABLE

Vacuum formed pans properly made from Sheffield FROST-WHITE-X Styrene Sheet are *guaranteed* light stable for 50,000 lighting hours. Highly flexible, even a 120° twist like this won't crack them!

Now you can take advantage of the economy and beauty of styrene in plastic pans for fluorescent fixtures. Vacuum-formed of Sheffield's FROST-WHITE-X sheet, these pans have a bright, white initial color, are more light stable than vinyl and other styrenes and cost only half as much as acrylic pans.

The sheet is Guaranteed Light Stable for 50,000 lighting hours and is backed by a written guarantee available to all vacuum formers and fixture manufacturers who form pans themselves. This is the only such Guarantee available to the industry on styrene pans or diffusers!!

Further, because of their flexibility and break-resistance, FROST-WHITE-X pans can be made in cross-sections as thin as 0.025 in.!! Consider the savings in material cost and shipping weight this can mean to you!!

FOR COMPLETE DETAILS on FROST-WHITE-X sheet or diffusers or the Sheffield Guarantee of Light Stability, contact your vacuum former or write to Sheffield Plastics, Inc., Dept. 92-B, Sheffield, Mass.

FIRST IN PLASTICS FOR LIGHTING

SHEFFIELD PLASTICS, INC.

SHEFFIELD, MASS.

(*Continued from page* 39A)

Green, Carl, 1542 S. St. Francis, Wichita, Kans.

INDIANA SECTION

Member:
*Lord, W. H., 6390 E. 34th St., Indianapolis, Ind.

Associate Members:
Kuhner, L. J., Electrical Equipment Co., Indianapolis, Ind.
Lester, E. L., 114 Ursal Lane, Greenwood, Ind.

MARITIME CHAPTER

Associate Members:
Rousay, J. R., Hub Electric, Campbellton, N. B.
Slaney, A. J., Meductic, N. B.

MARYLAND SECTION

Associate Members:
Butts, F. C., Frank Butts Associates, Baltimore, Md.
Ford, F. X., Graybar Electric Co., Baltimore, Md.

MICHIGAN SECTION

Member:
*Winn, V. L., Benjamin Electric Mfg., Dearborn, Mich.

Associate Members:
Barsamian, H. B., Electrical Engineering Associates, Inc., Detroit, Mich.
Miller, D. M., Westinghouse Electric Corp., Detroit, Mich.
Radden, Karl, Radden's Electric Co., Detroit, Mich.
Van Zanten, R. E., Westinghouse Electric Supply Co., Detroit, Mich.
Wida, J. J., 15940 Fleming, Detroit, Mich.
Zazaian, Sherman, Electrical Engineering Associates Inc., Detroit, Mich.

Student Member:
Pattison, R. J., GMC Truck & Coach Division, General Motors Corp., Pontiac, Mich.

MILWAUKEE SECTION

Member:
*Blitz, A. G., Wisconsin Public Service Corp., Green Bay, Wis.

Associate Members:
Augustine, J. C., Standard Electric Supply, Milwaukee, Wis.
Bence, L. A., Allen Bradley Co., Milwaukee, Wis.
Kuenn, D. G., 4615 W. Fountain Ave., Milwaukee, Wis.
Maloney, R. P., Sylvania Electric Products Inc., Milwaukee, Wis.

MISSISSIPPI SECTION

Associate Member:
Strickland, W. L., Colcock & Strickland & Co., Jackson, Miss.

MONTREAL SECTION

Members:
Chagnon, Jacques, C. E. Gravel, L'Abord-A-Plouffe, Que.
Magor, P. D., Wood, McAdam & Magor, Westmount, Que.
Ormerod, R. W. W., Canadian Westinghouse Co., Ltd., Montreal, Que.
Sicard, Marcel, Walter Dow & Co., Ltd., Montreal, Que.

Associate Members:
Grandmont, L., Ideal Electric, Inc., Montreal, Que.
Heczko, Z., Dominion Textile Co., Montreal, Que.
Mendels, D. N., Advance Transformer Co., Ltd., Montreal, Que.
Strother, Gerald, B. P. Canada, Ltd., Montreal, Que.
Vaillancourt, L. J., Crouse-Hinds Co. of Canada, Montreal, Que.

MOTHER LODE SECTION

Associate Members:
Baker, Clark, Jr., Smoot-Holman Co., Sacramento, Calif.
Cleland, G. L., Pacific Gas & Electric Co., Stockton, Calif.
Lamb, R. W., Ets-Hokin & Galvan, Stockton, Calif.
Morrill, H. E., Pacific Gas & Electric Co., Stockton, Calif.

NEW ENGLAND SECTION

Associate Members:

Heffernan, J. C., Sylvania Electric Products Inc., Danvers, Mass.

Yorke, C. H., Cleverdon, Varney & Pike, Boston, Mass.

NEW JERSEY SECTION

Members:

Neulinger, K. H., Westinghouse Electric Corp., Bloomfield, N. J.

Steinke, B. J., Dwight Engineering Associates, Englewood, N. J.

Associate Members:

Greenfield, D. W., Reliable Electrical Supply Co., Newark, N. J.

Huck, Kenneth, Reliable Electrical Supply Co., Newark, N. J.

Krug, H. A., Reliable Electrical Supply Co., Newark, N. J.

Krug, N. N., Reliable Electrical Supply Co., Newark, N. J.

Prupis, R. I., Moldcast Mfg. Co., Newark, N. J.

Rosen, Z. B., Good Friend Electrical Supplies, Inc., Toms River, N. J.

Sandoz, Josephine B., Silvray Lighting, Inc., Bound Brook, N. J.

Shulman, G. L., Litecraft Mfg. Corp., Passaic, N. J.

Smith, J. D., Public Service Electric & Gas Co., Newark, N. J.

NEW MEXICO CHAPTER

Member:

*Boehning, A. W., Jr., Boehning & Boehning Associated, Albuquerque, N. M.

Associate Member:

**Badsgard, W. A., Public Service Co. of New Mexico, Belen, N. M.

NEW ORLEANS SECTION

Associate Member:

Sudzik, J. D., Benjamin Electric Mfg. Co., Metairie, La.

NEW YORK SECTION

Associate Member:

Blumenstock, Alexander, Magnetic Amplifiers, Inc., New York, N. Y.

Webb, F. J., American Electric Power Service Corp., New York, N. Y.

Student Member:

Cicio, W. P., J. C. Penney Co., New York, N. Y.

NORTH TEXAS SECTION

Members:

*Chrismer, J. A., 6529 Linden Lane, Dallas, Texas.

Read, D. L., Pardue & Read, Wichita Falls, Texas.

Associate Members:

Briscoe, W. E., Progress Mfg. Co., Inc., Dallas, Texas.

Williams, J. H., Westinghouse Electric Corp., Dallas, Texas.

NORTHWESTERN OHIO SECTION

Associate Member:

Wiesler, S. H., Meckler Engineering, Toledo, Ohio.

OHIO VALLEY SECTION

Associate Member:

Tobias, Raymond, Litecraft Mfg. Corp., Loveland, Ohio.

OTTAWA CHAPTER

Associate Members:

Cress, E. A., Electrolier Mfg. Co., Ottawa, Ont.

Ross, C. P., Duro Test Electric, Ltd., Toronto, Ont.

PALMETTO SECTION

Member:

White, W. P., Industrial Electrical Consultants, Greenville, S. C.

Associate Member:

Efron, Marvin, 1120 B Ave., W. Columbia, S. C.

PHILADELPHIA SECTION

Member:

Daroff, M. A., U. S. Naval Air Engineering Facility, Naval Base, Philadelphia, Pa.

(Continued on page 42A)

ONLY TWO PIECES TO INSTALL

. . . and both Light-Weight

WITH GARCY "ULTRA-LUX"
Curved diffuser in 12" or 24" widths

OR 60TH ANNIVERSARY
Rectangular diffuser in 12" or 24" widths

It's a snap to install these Garcy fixtures. Only two basic parts to install, that's all. No on-the-job assembly work. End plates, diffuser panels and hinge fittings are all pre-assembled for you before shipment.

And Garcy fixtures are easy to handle. Even a lightweight like the gal above could handle these compact fixtures all day without tiring.

Find out for yourself how much on-the-job time you can save with Garcy fixtures.

Send for Bulletins 581-L and 582-L.

GARCY LIGHTING

division of Garden City Plating & Mfg. Co.
2475 Elston Ave., Chicago 47, Illinois

CHICAGO • NEW YORK • LOS ANGELES • TORONTO

lighting
design
by
mc Philben

45W wall mounted edge-lit

45R recessed
ceiling mounted edge-lit

cast aluminum
quality

mc Philben's 45 line edge-lit directionals are designed to blend with the finest contemporary decor in hotel lobbies, auditoriums, office buildings, schools and other public locations.

Gleaming satin finish . . . solid cast aluminum construction . . . wall, ceiling or surface mountings . . . incandescent and fluorescent models . . . invisibly hinged access doors . . . flush fasteners . . . acrylic Plexiglass inscription panels illuminating full length of letter . . . these are some of the features making mc Philben's 45 line edge-lit directionals the architect's first choice for use in the nation's finest buildings.

The 45 line series is available with either "exit" or special wording inscriptions. 4½", 6" or 8" lettering with red, green and white color combinations conform with all local regulations.

Contact your mc Philben representative today for full details. See our insert in Sweet's file or write for data sheet E/1.

mc Philben
LIGHTING COMPANY
1329 Willoughby Avenue
Brooklyn 37, New York

(*Continued from page* 41A)

Associate Members:
Blaese, R. C., General Electric Co., Philadelphia, Pa.
Cosgrove, T. F., General Electric Co., Philadelphia, Pa.
Davis, E. E., 500 Kingston Rd., Oreland, Pa.
Esoda, B. J., Philadelphia Electric Co., Philadelphia, Pa.
Galemmo, R. A., A. Ernest D'Ambly, Philadelphia, Pa.
Gaskill, R. E., Sun Oil Co., Philadelphia, Pa.
Gates, R. F., Federal Aviation Agency, National Aviation Facilities, Atlantic City, N. J.
Gorzelnik, E. F., Public Service Electric & Gas Co., Trenton, N. J.
Kohlhepp, Edward, 5223 N. Marshall St., Philadelphia, Pa.
Smith, G. J., Theo. W. Strauser, Newtown Square, Pa.
Stile, Edward, Edward Stile Interior Design, Philadelphia, Pa.
Whalen, C. J., Theo. W. Strauser, Newtown Square, Pa.

PITTSBURGH SECTION

Associate Member:
Neill, F. B., Leonard W. Neill, Uniontown, Pa.

PUGET SOUND SECTION

Member:
*Wells, J. H., Heinz & Wells, Seattle, Wash.
Associate Member:
Allen, Jack, Nu-Lite Corp., Seattle, Wash.

QUEBEC CHAPTER

Member:
Dorval, Oscar, 20 Rue St. Jean, Quebec, Que.
Associate Members:
Lapointe, Marcel, 45 des Bouleaux St. E., Quebec, Que.
St-Hilaire, C. H., BVD Co., Ltd., St. Romuald, Que.
Vallieres, G. H., Alexandre Frederick, Quebec, Que.
Vallieres, Marcel, Alexandre Frederick, Quebec, Que.

ROCHESTER SECTION

Associate Members:
Hamilton, T. M., Rohm & Haas Co., Philadelphia, Pa.
Strebel, G. A., E. K. Co., Rochester, N. Y.

ROCKY MOUNTAIN SECTION

Members:
Bryant, R. H., Rite Lite Supply Co., Denver, Colo.
Diercks, F. H., Scott Bros. Electric Co., Denver, Colo.
Associate Member:
Gibson, D. Y., Dept. of Public Works, Denver, Colo.

ST. LOUIS SECTION

Member:
Price, G. W., Sverdrup & Parcel, Inc., St. Louis, Mo.
Associate Members:
Ficker, O. H., E. H. Lauth & Associates, St. Louis, Mo.
Luzecky, C. M., Appleton Electric Co., St. Louis, Mo.
Mozena, D. C., Corning Glass Works, Brentwood, Mo.

SAN DIEGO SECTION

Members:
Kuntz, Seymour, 1933 Cable St., San Diego, Calif.
*McCutcheon, A. J., Jr., San Diego Gas & Electric Co., San Diego, Calif.
Associate Member:
Birchenall, James W., Hackett Ceiling & Lighting, Inc., San Diego, Calif.

SAN JACINTO SECTION

Associate Member:
Broussard, T. J., General Electric Co., Beaumont, Texas.

SAN JOSE CHAPTER

Associate Members:
Brennan, J. F., Day-Brite Lighting, Inc., Santa Clara, Calif.
Mulvany, R. L., City of San Jose, Department of Public Works, San Jose, Calif.
Raab, W. J., Sunsweet Growers Inc., San Jose, Calif.
Thompson, Charles, H. G. Wanderer, Sunnyvale, Calif.

SOUTHEAST FLORIDA SECTION

Associate Members:
Hertz, A. L., Weiss & Hertz, Coral Gables, Fla.
Mills, R. B., Thomas Industries, Inc., Moe Light Div., Ft. Lauderdale, Fla.
Schumacher, Earl W., Metropolitan Dade County, Miami, Fla.

SOUTHERN CALIFORNIA SECTION

Associate Members:
Brune, A. H., Southern California Edison Co., Alhambra, Calif.
Colbert, D. W., Department of Water & Power, Los Angeles, Calif.
Jensen, B. F., Southern California Edison Co., Whittier, Calif.
Umstead, D. L., Jr., Westinghouse Electric Corp., Los Angeles, Calif.
Wise, D. E., Southern California Edison Co., Compton, Calif.

SOUTHERN COLORADO CHAPTER

Associate Members:
Mader, L. W., Duro-Test Corp., Canon City, Colo.
McCann, E. D., Southern Colorado Power Co., Pueblo, Colo.

SOUTH PLAINS CHAPTER

Associate Member:
Foreman, L. V., Foreman Electric Co., Odessa, Texas.

TAR HEEL SECTION

Member:
Baker, J. F., Sylvania Lighting Products, Inc., Charlotte, N. C.
Associate Member:
Taylor, S. V., Westinghouse Electric Corp., Winston-Salem, N. C.

TORONTO SECTION

Associate Members:
Busbridge, Thomas, Ellis & Howard, Toronto, Ont.
Fee, Karl, Ruddy Electric Wholesale, Ltd., Peterboro, Ont.
Hobson, R. C., Ontario Department of Highways, Downsview, Ont.
Michael, E. S., Crouse-Hinds Co. of Canada, Ltd., Scarborough, Ont.
Morton, S. E., Canadian General Electric Co., Toronto, Ont.

TWIN CITY SECTION

Associate Members:
Enerson, Orlin, Bond Electric Co., St. Paul, Minn.
Freeland, N. E., Collins Electrical Construction Co., St. Paul, Minn.
Larson, R. W., Luxor Lighting Products, Inc., Minneapolis, Minn.
Martin, D. C., Lyman C. Gross, Consulting Engineer, Minneapolis, Minn.

UTAH SECTION

Associate Member:
Mitchell, A. L., Westinghouse Electric Supply Co., Salt Lake City, Utah.

VIRGINIA SECTION

Member:
Wood, A. Homer, The Joslyn Co., Richmond, Va.

WESTERN MICHIGAN SECTION

Associate Member:
Ernsberger, R. S., Warren S. Holmes Co., Lansing, Mich.

WESTERN NEW YORK SECTION

Associate Members:
Guminski, W. F., Jr., Niagara Mohawk Power Corp., Buffalo, N. Y.
Radel, L. T., Beman & Standeven, Buffalo, N. Y.
Reil, J. A., Ferguson Electric Construction Co., Buffalo, N. Y.
Student Member:
O'Connor, J. R., Tri Graphics Inc., Buffalo, N. Y.

WINNIPEG CHAPTER

Associate Members:

Astell, E. A., Astell Electric Co., Moose Jaw, Sask.

Larson, B. H., Saskatchewan Power Corp., Regina, Sask.

Nuttall, F. A., Keewintin Electric, Ltd., Winnipeg, Man.

Selby, T. A., Canadian Westinghouse Co., Ltd., Regina, Sask.

Vigrass, Lillian, Saskatchewan Power Corp., Regina, Sask.

YANKEE CHAPTER

Associate Members:

Lucia, A. J., Westinghouse Electric Supply Co., Springfield, Mass.

Welenc, L. M., Western Massachusetts Electric Co., Greenfield, Mass.

YOSEMITE CHAPTER

Associate Members:

Horwith, William, Horwith Electric Co., Fresno, Calif.

Paschall, J. A., Graybar Electric Co., Fresno, Calif.

EMPLOYMENT OPPORTUNITIES

LIGHTING DESIGNER AVAILABLE

Experienced in design of luminous ceilings, incandescent and fluorescent fixtures, and field coordination. Address Box 382, Publications Office, Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

LIGHTING SALES REPRESENTATIVE WANTED

By nationally known manufacturer of high quality specification commercial and institutional lighting fixtures (fluorescent and incandescent) and luminated ceiling systems. Qualified men should: 1. Know lighting and concentrate on architects and engineers; 2. Cover any of territories of: New York State, Louisiana, Illinois. We offer a modern product line, new catalog, illustrated detailed price sheet. Complete engineering information. We are Holophane licensees. Write full details to Box 388, Publications Office, Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

LIGHTING REPRESENTATIVES WANTED

Midwest manufacturer of quality, but competitive, Fluorescent Commercial and Industrial Lighting equipment has openings in the following territories: Iowa-Nebraska, Kansas, Missouri, Carolinas, and New York State. We manufacture a large stock line and also deal in specials. Write, giving qualifications and lines now represented, to Box 589, Publications Office, Illuminating Engineering Society, 1860 Broadway, New York 23, N.Y.

WANTED

~~DEAD~~ OR ALIVE

Manufacturers Representatives

Does the spirit of the old west still course through your veins and do you seek opportunities of the gold rush days?

A spanking new concept in lighting is now ready for the market. Here is a ground floor opportunity with a top drawer product. A few have already staked their claims but most sales areas are still open.

Write: Hi-Frequency Systems, Inc. Vermilion, Ohio

REWARD: UNLIMITED

CHAMPION
of the four major brands of lamps
CHAMPION
stands out for
VALUE
Light/per/dollar . . . the measure of value in lamps . . . delivered in full measure by Champion lamps . . . sound reason for choosing Champion's as your company's best buy.
CHAMPION Lamps
Incandescent
Fluorescent
Your best buy in lamps

CHAMPION LAMP WORKS, Lynn, Massachusetts

This FREE BOOKLET and SAMPLE

SHOW YOU WHY YOUR NEXT LUMINAIRES SHOULD BE OF

DYNASYL*

SPECULAR ALUMINUM
REFLECTOR SHEET
Pat. Applied For

The Brand New Idea in Light Reflecting Material!

- High specular reflectivity at lowest cost.
- Keeps its finish despite corrosive attack.
- Can be bent, drilled, punched, or crimped without damage to finish.
- Ready to form and use, no buffing or anodizing.
- Available in any gauge, temper or alloy.

MAIL THIS COUPON FOR FREE BOOKLET & SAMPLE TO:

W. J. RUSCOE COMPANY
LAMINATING DIVISION
483 Kenmore Blvd., Akron 1, Ohio

Name_____
Company_____
Street Address_____
City_____ State_____
Title_____

DYNASYL REFLECTIVE METALS PROCESS
* T.M. Reg. W. J. RUSCOE COMPANY, AKRON, OHIO.

PROFIT FROM THE VERSATILITY OF ATI GIMBAL RINGS

Buy ATI GIMBAL RINGS! Their adaptability and versatility mean a more desirable line to sell your customers and more profits for you.

They have many uses with PAR 38, 46, 56 and the 64 sideprong lamps as well as the R30, R40 and PAR 38 screwbase lamps. ATI Gimbal rings are coated to prevent rusting and provide an excellent paint base.

GIMBAL RING for PAR 38, 46, 56 and the 64 sideprong lamps.

GIMBAL RING for R30, R40 and PAR 38 screw-base lamps.

Write, wire or call for details

ATI ALEXANDER-TAGG INDUSTRIES, INC.
HATBORO, PENNSYLVANIA
OSborne 5-7200

HANDBOOK III NOW SHIPPED

Nearly 9000 prepublication orders for the new Third Edition, I.E.S. Lighting Handbook, have now been shipped.

Comments to date indicate a tremendous approval of the new work. New orders are coming in every day.

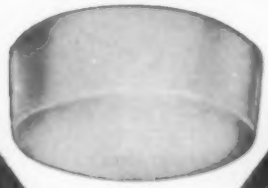
I.E.S. members who have not yet ordered their *one* Registered Member Copy at the special price of $7.50 should do so *now* to be right up to the minute in the latest lighting knowledge.

For non-members and extra copies for members, $10 per copy, postpaid. Quantity prices on request.

Order from:

Publications Office
ILLUMINATING ENGINEERING SOCIETY
1860 Broadway New York 23, N. Y.

ONLY THE LUMINOUS GLASS SHOWS



INCA 1175 LIGHTS

Now first in the U. S. A. INCA-LIGHTS are surface mounted, completely luminous incandescent fixtures—10"-12" or 14" in diameter. Holder permits the "Silverglo" bowl to conceal all metal parts—the bowl tilts on or off in a twinkle for easy cleaning. Write for catalog today.

U. S. PATENT NO. 645,184

J. A. WILSON LIGHTING and DISPLAY, Inc.
1500 Industrial Drive, Erie, Pennsylvania
Dedicated to Illumination through Science to Service
PARAGRID-TILE • LUVE-TILE • FLUORESCENT LIGHTING

INDEX TO ADVERTISERS
May 1959

Advance Transformer Co. Inside Front Cover

Alexander-Tagg Industries, Inc. 44A

All-Brite Fluorescent Fixtures Inc. 25A

American Express Co. 29A

Certified Ballast Manufacturers Inside Back Cover

Champion Lamp Works 43A

Contrex Co. 45A

Corning Glass Works 1A

Crouse-Hinds Co. 11A

Day-Brite Lighting Inc. 2A

Garden City Plating & Mfg. Co. 41A

General Electric Co., Lamp 31A

Edwin F. Guth Co. 39A, Back Cover

Hi-Frequency Systems, Inc. 43A

Kerrigan Iron Works, Inc. 21A

KSH Plastics, Inc. 19A

Lighting Dynamics 35A

Lighting Products, Inc. 27A

Litecontrol Corp. 4A

McPhilben Lighting Co. 42A

Monsanto Chemical Co. 33A

Perfeclite Co. 15A

Rambusch Decorating Co. 32A

Revere Electric Mfg. Co. 16A

Rotuba Extruders Inc. 34A

W. J. Ruscoe Co., Laminating Div. 44A

Sheffield Plastics Inc. 40A

Smithcraft Lighting Div. 12A, 13A

Sola Electric Co. 46A

Sunbeam Lighting Co. 30A

Sylvania Electric Products Inc. 36A

Union Metal Mfg. Co. 38A

John C. Virden Co. 8A

Wheeler-Fullerton Lighting Div. 22A

Wide-Lite Corp. 37A

J. A. Wilson Lighting & Display 44A

THE NEW YORK TELEPHONE COMPANY AND LEADING UTILITIES ARE MEETING THESE IMPORTANT REQUIREMENTS...

ACOUSTICS LIGHTING SAFETY

3 IN 1

with CONTREX SOUNDSHEET

Contrex Soundsheet, the only medium to successfully combine balanced sound absorption and excellent light diffusing properties, is being installed nationwide in prominent utility buildings. This exciting new architectural tool provides more sound absorption at low and high frequencies than the accepted types of acoustical treatment, and at the same time, offers highly efficient, diffused, shadow-free illumination.

Installation of Contrex Soundsheet — Operating Room, Forest Hills Telephone Building, New York Telephone Company.

Soundsheet installation in Operating Room, Smithtown Telephone Building, New York Telephone Company.

Soundsheet is featured in the lighting equipment of these leading manufacturers of lighting: The Wakefield Co., *Vermilion, Ohio*; Luminous Ceilings, Inc., *Chicago, Ill.*; Smithcraft Lighting, *Chelsea, Mass.*; Sylvania Electric Products, *Wheeling, W. Va.*; Fullerton Manufacturing Co., *Norwalk, Conn.*; Litecraft Manufacturing Corp., *Passaic, N.J.*; Lumenated Ceiling Division, Thermatank Inc., *Detroit, Mich.*; Wakefield Lighting Ltd., *London, Ontario, Canada*; Lighting Products Inc., *Highland Park, Ill.*; Lumi-Lucent Ceilings Co., *Cleveland, Ohio*; Canadian Westinghouse Supply Co. Ltd., *Montreal, Canada*; Louverall Lighting Corp., *Beverly Hills, Cal.*; Columbia Electric & Manufacturing Co., *Spokane, Wash.*; Pittsburgh Reflector Co., *Pittsburgh, Pa.*; Architectural Ceilings, Inc., *New York, New York*.

Write today for a reprint of ILLUMINATING ENGINEERING's "Acoustics and Lighting" by George W. Clark, a factual report on lighting and sound conditioning equipment.

Meets strict UL, F.I.A. and Factory Mutual requirements.

Listed for use under sprinkler systems, Soundsheet will not support combustion and is *ideal* for installation in overall ceilings and partitions now in existence or in the planning stage. Easy to install, easy to maintain, and attractive in appearance, Soundsheet is available in corrugated or flat sheet, translucent or opaque, in white or a color.

Developed for Contrex by Bolt Beranek and Newman, Inc.

MAIL TO:
CONTREX
CHELSEA 50, MASS.

☐ Please send me a reprint of IE's "Acoustics and Lighting" by George W. Clark, as well as literature and a sample of Soundsheet.
☐ Please have your representative call.

NAME _____
COMPANY _____
ADDRESS _____
CITY _____ STATE _____

IE-5

100% CBM CERTIFIED

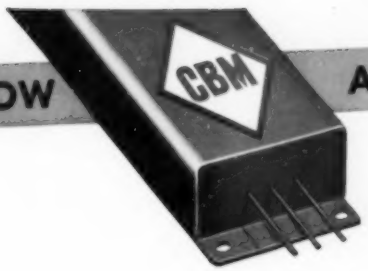
Sola ballasts guard your reputation with 100-percent CBM certification. There is no "second line" at Sola.

Every Sola fluorescent ballast for general-lighting service, for which a CBM specification exists, is a CBM-certified ballast—and then some! They top CBM specs by comfortable margins. You can install, furnish, or specify Sola knowing that reserve tolerances—conservatively engineered into every unit—assure full-rated ballast life and light output.

Lamps and fixtures operating with cool, efficient, trouble-free Sola ballasts deliver all the performance demanded by their designers. The man who's buying the light expects nothing less, and it's up to the contractor, the fixture manufacturer, and the engineer to see that he gets it. Sola ballasts guard your reputation. Why not call your district sales engineer and get the facts. ***Sola Electric Co.*** (A Division of Basic Products Corporation) ***4633 W. 16th Street, Chicago 50, Illinois.***

SOLA BALLASTS

HOW CBM ASSURES YOU BETTER BALLAST VALUE



Unannounced visitor picks random samples from production line of each Certified Ballast Manufacturer for monthly ETL test . . . so you can be sure CBM symbol always means "up to specification"

THIS gives you *extra* assurance of CBM quality. At least once each month, an ETL inspector "just happens" to visit the plant of every Certified Ballast Manufacturer . . . and picks random samples right from the production line. Each sample is clearly marked and dated to prevent substitution; all must be shipped to Electrical Testing Laboratories for test against the CBM specification. Should any fail to meet it, the right to use the CBM emblem is withdrawn until the condition is corrected.

Behind this positive assurance of continuing CBM quality is the CBM specification, that provides dependable performance, better ballast value, including:

High power factor • Long ballast life
High light output • Low cost of illumination
Long lamp life

And of course, Certified CBM Ballasts are UL listed.

For one very practical slant on why Certified CBM means better ballast value and better performance from fluorescent fixtures, write for: "Why High Power Factor Ballasts cut your lighting costs".

CBM CERTIFIED by ETL

CERTIFIED BALLAST MANUFACTURERS

2112 KEITH BUILDING
CLEVELAND 15, OHIO

Participation in CBM is open to any manufacturer who wishes to qualify

3-59

NEW
GUTH KOLORKODED* industrial fixtures with built-in

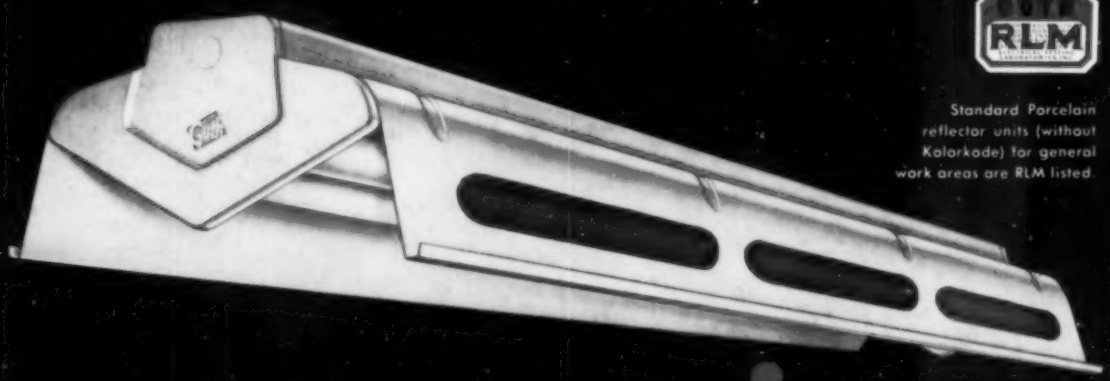
TRAFFIC LIGHTS

Designed to direct traffic, protect your workers, identify various plant or storage areas . . . and create new standards of seeing-efficiency for greater productivity.

They "wash away" ceiling shadows, yet assure high footcandles with comfortable shielding for the working level: 10% uplight with 13° cut-off or 25% uplight with 27° cut-off . . . for 430, 800 or 1500 M. A. operation. Easy installation and maintenance. Three reflector finishes—Permalux White, Porcelain or Alzak Aluminum.

WRITE FOR FREE KOLORKODED BULLETIN

*Copyright &U.S. & Can. Pats. applied for.



RLM

Standard Porcelain reflector units (without Kolorkade) for general work areas are RLM listed.

at exits, fire protection systems, keep-out areas, etc.

at stairs, curbs, dead ends and other hazard areas.

in aisles, safe storage, first-aid, etc.

Guth LIGHTING

THE EDWIN F. GUTH CO.
2615 Washington Blvd., St. Louis 3, Mo.
TRUSTED NAME IN LIGHTING SINCE 1902